BAGHOUSES

Compliance Assistance Program

California Environmental Protection Agency
Air Resources Board

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100 INTRODUCTION

This manual is a product of the California Air Resources Board (CARB). The Air Resources Board was created by the California Legislature to control air pollutant emissions and to improve air quality throughout the State. It works closely with the United States Environmental Protection Agency (EPA) and local air pollution control districts in improving air quality in California.

Particulate Emissions

This manual provides information on baghouses, which are used as control devices to curtail the emission of particulate matter from a large range of industrial and commercial sources. Baghouses and other particulate control devices are installed at facilities to reduce the **particulate emissions** from these facilities to quantities within the limits prescribed in air pollution regulations. Noncompliance with these regulations often results when the performance of the control devices falters.

Because many areas of California do not attain the State or the national ambient air quality standards for particulate matter, CARB has traditionally sought to reduce noncompliance rates by providing an adequate deterrent through enforcement action against violators. In conjunction with this, CARB seeks to reduce noncompliance rates and the associated excess emissions by ensuring that the emission source operator has:

1. A basic understanding of the rules to which the source is subject;

2. A basic understanding of how compliance is determined.

CARB established the Compliance Assistance Program (CAP) as a means to provide this basic understanding.

Continuous Compliance

If California's non-attainment areas are to have any chance of attaining the ambient air quality standards, the excess emissions resulting from non-compliance must be reduced by air pollution control inspectors and industry personnel. Air pollution control inspectors can identify problems for the source operator, but their periodic visits cannot ensure **continuous compliance.** Ensuring this is the job of educated source operators. The goal of CAP is thus twofold:

1. To help air pollution control districts develop and maintain inspector knowledge;

2. To encourage industry to do self-inspections for continuous compliance.

100 INTRODUCTION

Audience

This manual is written for district inspectors and for operators at facilities with baghouses. It is designed to serve district inspectors as a training guide on baghouses and on how to inspect them. It is also designed to supplement the operating manuals that baghouse vendors provide their clients. We hope that this manual is detailed enough for the district inspector, and concise enough for the source operator.

Section 200 of this manual describes the rules to which a source with a baghouse is subject. Both the summaries of rules and the texts of applicable statutes are presented.

Section 300 gives an overview of the theory fundamental to the design of baghouses. It then describes baghouse design types and baghouse hardware.

Section 400 details inspection procedures for district inspectors. Some of these procedures may be used by source personnel in performing an internal audit.

Section 500 discusses troubleshooting procedures. This section is of greater benefit to source operators than it is to district personnel.

Section 600 lists recommended regular maintenance activities and safety procedures.

References

References are located in appendix A.

200 RULE DISCUSSION

Plants that emit particulate matter are subject to the following requirements:

Rules

1. General prohibitions which include:
   - Visible emissions limit;
   - Particulate matter emissions limit;
   - Fugitive dust emissions;

Permits

2. **Permit** to Operate;

3. Equipment Breakdown rule.

These requirements are discussed in a separate section of this chapter.

Should the source experience difficulty in complying with these requirements, sources and district personnel should be familiar with the applicable variance provisions.

Federal Standards

Many plants must also operate in compliance with the applicable **Federal New Source Performance Standards** (NSPS).

Capture Efficiency

Baghouses are particulate control devices used at many industrial and commercial facilities. A baghouse collects particulate matter entrained in a process' effluent gas stream, and keeps most of the particulate matter from being emitted out the stack and into the atmosphere. Many baghouses are designed to **capture** over 99.9 percent of the particulate matter ducted through them.

When baghouses are operating at or near design standards, the particulate matter passsing out the stack should not be of quantities sufficient to violate the regulatory limits. However, changes in process (such as production rate) and degradation of baghouse components over time will alter the particulate emission rate, perhaps pushing it over regulatory limits.

Source operators should have a clear and up-to-date understanding of both the regulatory requirements and the efficiency with which their baghouses are capturing particulate matter. The remainder of this section outlines some of the regulatory requirements.

200 RULE DISCUSSION

201 VISIBLE EMISSIONS

All of the local air pollution districts in California have a visible emissions prohibitory rule. These rules vary in wording, but in almost all cases they express the following:

"... no person shall discharge into the atmosphere from any source whatsoever any contaminant, other than uncombined water vapor, for a period or periods aggregating more than three minutes in any one hour which is:

20 % Opacity

(a) As dark or darker in shade as that designated as No. 1 (or 20% **opacity**) on the Ringelmann Chart, as published by the United States Bureau of Mines, or

(b) Of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in subdivision (a)."

The State standard for visible emissions (section 41701, California Health and Safety Code) is No. 2 on the Ringelmann Chart, or 40% opacity.

Ringelmann Chart

The **Ringelmann Chart** is a device used for determining whether emissions of smoke are within established limits or standards of permissibility (statutes and ordinances) with reference to the Ringelmann Chart. Smoke density in a plume is compared with a series of graduated shades of grey on the Ringelmann Chart, and the smoke density is thus judged by the viewer. EPA Reference Method 9 describes in detail how such visible emission evaluations should be properly performed, and how to be certified to perform them. The Compliance Division of the ARB trains and certifies government and industry personnel in visible emissions evaluations at its popular "Fundamentals of Enforcement" class which is offered four times a year. Certified personnel are required to recertify every six months in order to demonstrate ongoing evaluation skill.

When reducing the data, the inspector should aggregate the readings taken over 15-second time intervals where the opacity was observed to exceed the Ringelmann limit. Every aggregate of over three minutes of such readings, made in a one hour period, constitutes a violation. This data reduction method reflects the visible emissions limitation in California Health and Safety Code (HSC) section 41701. Note that this procedure of data reduction results in more stringent emissions limitations than the Federal method as stated in Method 9. According to Method 9, opacity is determined as an average of 24 consecutive observations recorded at 15 second intervals (i.e., six consecutive minutes of readings, averaged).

202 PARTICULATE MATTER EMISSION LIMITS

Air pollution control districts have either a particulate-matter-by-concentration rule or a solid-particulate-matter-by-weight rule. Some districts have both rules. Baghouses are often used to reduce particulate emissions below the allowed levels.

A concentration rule puts limitations on the maximum concentration of particulate matter allowed to be emitted based on the volume flowrate of gas discharged, both being calculated as dry gas at standard conditions.

A solid-particulate-matter-by-weight rule limits the maximum discharge rate allowed for solid particulate matter (aggregate weight discharged from all points of a process in one hour) based on the process rate (weight per hour).

For the purposes of these rules, emissions are averaged over one complete cycle of operation or one hour, whichever is the lesser time period.

Typical particulate matter emission-limiting rules are presented in **appendix B** of this manual.

Appendix B

ARB Method 5 is used in most air districts to souce test a facility with a baghouse for the determination of particulate emissions. This method is presented in **appendix C** of this manual.

Appendix C

The Federal Clean Air Act requires the EPA to establish new source performance standards (NSPS) for categories of sources which significantly contribute to air pollution. The NSPS apply both to new sources and to modifications to sources. The Clean Air Act directly prohibits operation of sources in violation of NSPS. EPA has the authority to delegate enforcement to the states and has delegated primary authority to several local districts in California.

Facilities subject to NSPS have specified particulate matter emission limits that are to be measured by means of EPA Method 5. This test method differs from ARB Method 5. For additional details on these test methods please see section 404 of this manual. The EPA method can be found in the Code of Federal Regulations, 40 CFR 60, Appendix A, Method 5.

200 RULE DISCUSSION

203 PERMIT CONDITIONS

Under the authority of the California Health and Safety Code (H&SC), and in order to comply with the California State Implementation Plan and New Source Performance Standards where applicable, the districts issue conditions for the operation of industrial and commercial processes and the related emission control equipment.

PO

Sources must function within the parameters stated in the **Permit to Operate (PO)** issued by the district. Failure to do so is a violation of permit conditions.

The conditions stated on a PO with regard to a baghouse vary widely. Some examples are:

1. Limits on the grain loading of stack effluent;
2. Limits on the process weight. This kind of limit works in conjunction with a particulate-matter-by-weight rule. In such a case, the rule specifies the maximum discharge rate allowed for effluent particulate matter based on the process weight per hour;
3. Allowable ranges of baghouse inlet and outlet temperatures;
4. Maximum boiler (process) firing rate;
5. Recordkeeping requirements;
6. Requirements for continuous emission monitors (CEM) regarding calibration, drift, recordkeeping.
7. Maximum pressure drop across the bags.

Permits to Operate should be posted in the location designated by the instructions on the permit or in the district rule.

204 EQUIPMENT BREAKDOWN PROVISIONS

Each district has an equipment breakdown (or excusable equipment malfunction) rule. The rule enables a source qualifying under stated conditions to avoid enforcement action otherwise precipitated by failure of that source to comply with air pollution regulations as a result of a malfunction of any air pollution control equipment or related operating equipment. Malfunctions of in-stack monitoring equipment are also addressed in the rule.

Sources should keep a copy of the breakdown rule on location. They should also be familiar with their responsibilities in the event of an equipment malfunction.

Qualifications for Breakdown Provisions

The conditions that a malfunction must meet in order to **qualify for district breakdown provisions** vary from district to district. Typically, the following are conditions for an acceptable breakdown:

1. The breakdown must result from a failure that was unforseeable;
2. It must not be the result of neglect or disregard of any air pollution control law or rule or regulation;
3. It must not be intentional, or the result of negligence;
4. It must not be the result of improper maintenance;
5. It must not constitute a nuisance; and
6. It must not be an abnormally recurrent breakdown of the same equipment.

District rules also list a number of procedures which must be followed in reporting the breakdown in a timely manner to the district. If the breakdown is not reported to the district within the allowed time period, as stated in the rule, a separate violation occurs, for which enforcement action is appropriate.

When a breakdown is reported to the district it is recorded in the district's breakdown log. Sources must provide the district with the following information:

1. The source's name and location, and the source contact's name and telephone number;

2. The specific equipment affected by the breakdown;

3. The specific equipment that failed;

4. The date and time that the breakdown occurred;

5. The date and time that the breakdown is being reported to the district; and

6. The source's proposed action.

District Investigation

Upon receipt of a breakdown report, the **district performs an investigation** to determine whether the malfunction meets the prescribed breakdown conditions. This investigation includes an on-site inspection of the malfunctioning equipment. If the inspector does not find a breakdown condition at the source, he may take appropriate enforcement action including, but not limited to, seeking fines, an abatement order, or an injunction against further operation.

If a source files a breakdown report which falsely, or without probable cause, claims a malfunction to be a breakdown occurrence, this shall constitute a separate violation. The burden of proof shall be on the source to provide sufficient information that a breakdown did occur. If the source fails to do this, the district will undertake appropriate enforcement action.

Emergency Variance

A source with a breakdown must take immediate steps to correct the equipment malfunction as quickly as possible. If a source finds that a malfunction cannot be repaired within the district's allowable duration of a breakdown, the source may file for an **emergency variance** in order to avoid enforcement action.

District rules require sources to submit in writing the following details to the district air pollution control officer within a stated time period of the correction of the breakdown occurrence:

1. The duration of excessive emissions;

2. An estimate of the quantity of excess emissions;

3. A statement of the cause of the occurrence;

4. Corrective measures to be taken to prevent recurrences; and

5. **Proof** of the source's return to compliance, including the date and time that the breakdown was corrected.

Proof

Besides the information mentioned above, the district log will also include the following items, some of which will be filled in as the case continues:

1. A confirmation that the breakdown is allowable under district rules;

2. The name of the district investigator;

3. The initial inspection file number;

4. The compliance confirmation inspection file number;

5. The date that the breakdown correction report was filed by the source; and

6. An indication if a variance was requested.

205 VARIANCES

A source may petition for a variance if either of the following is true:

1. Pollution control equipment has broken down and meets the criteria for breakdown condition under district rules; however, the source operator finds that it will take longer to repair the breakdown than provided for under the district breakdown rule. In such a case, a source operator may wish to apply for an emergency variance.

2. A source finds itself to be out of compliance, is found to be out of compliance, or expects to soon be out of compliance, with any air pollution control district rule or regulation, or with Section 41701 of the California Health and Safety Code (H&SC).

If a source falls into either of the above categories at any time, it should consider applying for a variance. A source's purpose in petitioning for a variance is to attempt to shield itself from enforcement action while it is out of compliance. Sources should be advised that the initiative to file for a variance rests upon them. Table 205.1 provides a quick reference to variance procedures.

When a source applies for a short variance (90 day maximum) or a regular variance (1 year maximum unless a schedule of increments of progress is included), it is also applying for an interim variance, which gives the source protection from enforcement action until the next Hearing Board meeting, or up to a 90 day period, whichever is shorter. Interim and emergency variance orders, if issued, are typically granted the same day they are requested. A written petition must be submitted before these (and all other) variances are granted.

It is the source's responsibility to estimate the amount of time for which it wishes to be under variance, and to then apply for the corresponding type of variance.

Hearing Board

A source should be aware that the decision on whether to grant any variance rests with the district **Hearing Board** and not with the air pollution control officer or that person's staff. In general, the more information a source provides to the Hearing Board concerning its compliance problem, the better are its prospects of being granted a variance.

Table 205.1 Variance Procedures

Variance Quick Reference

Types of Variances	Effective Time Span	Noticing Requirements	Further considerations
Emergency	30 Day Maximum HSC Section 42359.5	None HSC Section 42359.5	1 member may issue Hearing Board determines eligibility for Emergency HSC Section 42359.5
Short	90 Day Maximum HSC Section 40825	10 Day Minimum to APCO, Air District, ARB,EPA, and Petitioner HSC Section 40825	1 Hearing Board member may hear if District pop. is less than 0.75 million, unless any member of the public objects. HSC Section 40825
Interim	90 Day Maximum or until next Hearing Board meeting, whichever occurs first HSC Section 42351(b)	Reasonable notice to APCO and Petitioner HSC Section 40824	same as Short variance HSC Section 40824
Regular	1 year Maximum unless schedule of increments of progress is included HSC Section 42358	30 Day Minimum to APCO, Air Basin District, ARB, EPA, Petitioner and any interested member of the public HSC Section 40826	Public notice of hearing in at least one newspaper of general circulation in District HSC Section 40826
Modification of Final Compliance Date (Extension)	Determined by Hearing Board	same as Regular variance HSC Section 40826	same as Regular variance HSC Section 40826
Modification of Increments of Progress	Determined by Hearing Board	10 Days Minimum to APCO, Air Basin District, ARB, EPA and petitioner HSC Section 40825	same as Interim variance HSC Section 40825
Interim Authorization	30 Day Maximum HSC Section 42351.5	Reasonable notice to APCO and Petitioner HSC Section 40824	No more than one granted application if modification of schedule (May be heard by 1 Hearing Board member if District pop. is less than 0.5 million) HSC Section 42351.5

NOTES: HSC Section 42352: to qualify for a variance source must meet six criteria

1. In violation of HSC Section 41701 or District Rules and Regulations
2. Compliance would require unreasonable taking of property or closing or elimination of business
3. Closing or taking would not have significant impact on reducing pollutants
4. Petitioner has considered limiting operation to applying for a variance
5. During the variance, Petitioner will reduce excess emissions to the maximum level feasible
6. Petitioner must quantify or monitor excess emissions while variance is in effect, if requested by the District

HSC Section 42358: Variance must specify an effective time and final compliance date

HSC Section 42360: Copy of the order must be received by ARB within 30 days of granting

HSC Section 42362, 42363: ARB may revoke or modify variance by public hearing and 30 day notice

HSC Section 42356: District Hearing Board may also modify or revoke variance

This table is for quick reference only. Please refer to the Health and Safety Code for complete variance information

200 RULE DISCUSSION

Rules for variance procedures vary somewhat from district to district. The district rules are based on H&SC statutes. Some of the applicable statutes are listed in section 206 of this manual. District personnel as well as source operators should be familiar with these statutes and with the local district variance rule.

With regard to variances, State law (H&SC) requires that:

1. The district should not allow sources to operate in violation of district rules without a variance, even if the source is working towards finding a solution to the problem. Source operators should be aware that under H&SC Section 42400.2, if they continue to operate in violation of district rules, they are subject to a $25,000 per day fine and up to 12 months in county jail.

2. All variance hearings should be noticed properly in accordance with H&SC Sections 40823 through 40827. Section 40826 requires a 30-day notice period for hearings for variances over a 90-day duration.

3. No variance shall be granted unless the Hearing Board makes all of the findings listed in H&SC, Section 42352. Notice that parts (d) through (f) were added by the California Clean Air Act, which became effective January 1, 1989. See table 205.1 for a summary of noticing requirements.

The Air Resources Board recommends that the following procedures be observed in the various stages involved from the time a source petitions for a variance, through the end of the variance period. Some of these recommendations may not be a part of all districts' variance programs at this time; or, they may be written but not implemented procedures.

1. Parties petitioning for variances should be required to fill out a petition form in writing.

2. The district will require sources to provide excess emissions figures on the petitions they submit. This information will be evaluated by the District staff. The emission figures are be presented to the Hearing Board, so that the Board formally recognizes, and the public may be aware of, the emissions impact of the variance. If the variance is granted, these limits must be included in the final variance order.

3. An **interim variance** should be granted to cover the time period from filing the petition for a regular variance until a decision is rendered on whether the variance is granted. This interim variance can subject the source to operating conditions during that interim period.

Interim Variance

4. Variances should **not be granted retroactively.** The date that variance coverage begins cannot predate the date on which the petition was filed.

Not Retroactive

5. Each variance order will specify the equipment under variance and the district rule or regulation violated. By doing this, protection from enforcement action and the emissions resulting from granting the variance will be limited.

6. The district should schedule increments of progress for sources under variance, and should verify that the source is meeting these.

7. The district should require the source to quantify excess emissions that will occur during the period of variance, and to report these excess emissions according to a schedule.

8. At the end of the variance period, the **district shall inspect** the source to ensure that it is in compliance with all district air pollution regulations.

District Inspection

200 RULE DISCUSSION

206 HEALTH AND SAFETY CODE

The following California Health and Safety Code references are included to demonstrate the authority of district air pollution control districts to adopt regulations, issue permit conditions, perform inspections and pursue enforcement action. The relevant Health and Safety Code Sections are presented in numerical order:

39000 Legislative Findings - Environment
39001 Legislative Findings - Agency Coordination
39002 Local and State Agency Responsibilities
39003 ARB Responsibilities
40000 Local/State Responsibilities
40001 Adoption and Enforcement of Rules and Regulations
40702 Adoption of Rules and Regulations
41509 No Limitation on Power to Abate Nuisance
41510 Right of Entry With Inspection Warrant
41700 No Person Shall Discharge Pollutants (Public Nuisance)
41701 No Emissions Shall Exceed Ringelmann 2 (Ringelmann/ Opacity Standards)
42300 District Permit System
42301 Requirements For Permit Issuance
42301.6 Permit Approval: Powers and Duties of Air Pollution Control Officer
42301.7 Air Contaminants, Threatened Release
42303 Air Contaminant Discharge: Information Disclosure
42303.5 False Statements in Permit Applications
42304 Permit Suspension (Failure to Supply Information)
42400 General Violations, Criminal
42400.1 Negligence, Criminal
42400.2 Document Falsification or Failure to Take Corrective Action, Criminal
42400.3 Willfully and Intentionally Emitting an Air Contaminant
42401 Violating Order of Abatement, Civil
42402 General Violations, Civil
42402.1 Negligence or Actual Injury, Civil
42402.2 Document Falsification or Failure to Take Corrective Action, Civil
42402.5 General Violations, Administrative Civil (Administrative Penalties)
42403 Civil Penalties
42404.5 Statute of Limitations for Civil Actions

LEGAL REQUIREMENTS

INTRODUCTION

The California Legislature passes laws, called statutes, that authorize Executive branch agencies (such as the Air Resources Board) to implement laws, through regulations, pursuant to the directives of the statutes.

Regulations adopted by the Air Resources Board (ARB) are found in the California Code of Regulations (CCR). Each regulation cites specific sections of the Legislative codes as authority and as references.
The following information is designed to provide a general background of the applicable laws and regulations; first, the Health and Safety Code (HSC), then the California Code of Regulations (CCR).

LEGAL REQUIREMENTS

HEALTH AND SAFETY CODE

The following California HSC references are included to provide you with the basis for California Air Pollution Control Laws. The relevant HSC sections are presented in numerical order.

LEGISLATIVE FINDINGS-ENVIRONMENTAL - 39000

The Legislature finds and declares that the people of the State of California have a primary interest in the quality of the physical environment in which they live, and that this physical environment is being degraded by the waste and refuse of civilization polluting the atmosphere, thereby creating a situation which is detrimental to the health, safety, welfare, and sense of well-being of the people of California.

LEGISLATIVE FINDINGS-AGENCY COORDINATION - 39001

The Legislature, therefore, declares that this public interest shall be safeguarded by an intensive, coordinated state, regional, and local effort to protect and enhance the ambient air quality of the state. Since air pollution knows no political boundaries, the Legislature declares that a regional approach to the problem should be encouraged whenever possible and, to this end, the state is divided into air basins. The state should provide incentives for such regional strategies, respecting, when necessary, existing political boundaries.

LOCAL AND STATE AGENCY RESPONSIBILITIES - 39002

Local and regional authorities have the primary responsibility for control of air pollution from all sources other than vehicular sources. The control of vehicular sources, except as otherwise provided in this division, shall be the responsibility of the State Air Resources Board. Except as otherwise provided in this division, including, but not limited to, Sections 41809, 41810, and 41904, local and regional authorities may establish stricter standards than those set by law or by the state board for nonvehicular sources. However, the state board shall, after holding public hearings as required in this division, undertake control activities in any area wherein it determines that the local or regional authority has failed to meet the responsibilities given to it by this division or by any other provision of law.

ARB RESPONSIBILITIES - 39003

The State Air Resources Board is the state agency charged with coordinating efforts to attain and maintain ambient air quality standards, to conduct research into the causes of and solution to air pollution, and to systematically attack the serious problem caused by motor vehicles, which is the major source of air pollution in many areas of the state.

LOCAL/STATE RESPONSIBILITIES - 40000

The Legislature finds and declares that local and regional authorities have the primary responsibility for control of air pollution from all sources, other than emissions from motor vehicles. The control of emissions from motor vehicles, except as otherwise provided in this division, shall be the responsibility of the state board.

ADOPTION AND ENFORCEMENT OF RULES AND REGULATIONS - 40001

(a) Subject to the powers and duties of the state board, the districts shall adopt and enforce rules and regulations to achieve and maintain the state and federal ambient air quality standards in all areas affected by emission sources under their jurisdiction, and shall enforce all applicable provisions of state and federal law.
(b) The rules and regulations may, and at the request of the state board shall, provide for the prevention and abatement of air pollution episodes which, at intervals, cause discomfort or health risks to, or damage to property of, a significant number of persons or class of persons.
(c) Prior to adopting any rule or regulation to reduce criteria pollutants, a district shall determine that there is a problem that the proposed rule or will alleviate and that the rule or regulation will promote the attainment or maintenance of state or federal ambient air quality standards.

ADOPTION OF RULES AND REGULATIONS - 40702

200 RULE DISCUSSION

A district shall adopt rules and regulations and do such acts as may be necessary or proper to execute the powers and duties granted to, and imposed upon, the district by this division and other statutory provisions. No order, rule, or regulation of any district shall, however, specify the design of equipment, type of construction, or particular method to be used in reducing the release of air contaminants from railroad locomotives.

NO LIMITATION ON POWER TO ABATE NUISANCE - 41509

No provision of this division, or of any order, rule, or regulation of the state board or of any district, is a limitation on:
(a) The power of any local or regional authority to declare, prohibit, or abate nuisances.
(b) The power of the Attorney General, at the request of a local or regional authority, the state board, or upon his own motion, to bring an action in the name of the people of the State of California to enjoin any pollution or nuisance.
(c) The power of a state agency in the enforcement or administration of any provision of law which it is specifically permitted or required to enforce or administer.
(d) The right of any person to maintain at any time any appropriate action for relief against any private nuisance.

RIGHT OF ENTRY WITH INSPECTION WARRANT - 41510

For the purpose of enforcing or administering any state or local law, order, regulation, or rule relating to air pollution, the executive officer of the state board or any air pollution control officer having jurisdiction, or an authorized representative of such officer, upon presentation of his credentials or, if necessary under the circumstances, after obtaining an inspection warrant pursuant to Title 13 (commencing with Section 1822.50), Part 3 of the Code of Civil Procedure, shall have the right of entry to any premises on which an air pollution emission source is located for the purpose of inspecting such source, including securing samples of emissions therefrom, or any records required to be maintained in connection therewith by the state board or any district.

NO PERSON SHALL DISCHARGE POLLUTANTS [PUBLIC NUISANCE] - 41700

Except as otherwise provided in Section 41705, no person shall discharge from any source whatsoever such quantities of air contaminants or other material which cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public, or which endanger the comfort, repose, health, or safety of any such persons or the public, or which cause, or have a natural tendency to cause, injury or damage to business or property.

NO EMISSIONS SHALL EXCEED RINGELMANN 2 [RINGLEMAN/ OPACITY STANDARDS] - 41701

Except as otherwise provided in Section 41704, or Article 2 (commencing with Section 41800) of this chapter other than Section 41812, or Article 2 (commencing with Section 42350) of Chapter 4, no person shall discharge into the atmosphere from any source whatsoever any air contaminant, other than uncombined water vapor, for a period or periods aggregating more than three minutes in any one hour which is:
(a) As dark or darker in shade as that designated as No. 2 on the Ringelmann Chart, as published by the United States Bureau of Mines, or
(b) Of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in subdivision (a).

DISTRICT PERMIT SYSTEM - 42300

(a) Every district board may establish, by regulation, a permit system that requires, except as otherwise provided in Section 42310, that before any person builds, erects, alters, replaces, operates, or uses any article, machine, equipment, or other contrivance which may cause the issuance of air contaminants, the person obtain a permit to do so from the air pollution control officer of the district.
(b) The regulations may provide that a permit shall be valid only for a specified period. However, the expiration date of any permit shall be extended upon completion of the annual review required pursuant to subdivision (e) of Section 42301 and payment of the fees required pursuant to Section 42311, unless the air pollution control officer or the hearing board has initiated action to suspend or revoke the permit pursuant to Section 42304, 42307, or 42390, that action has resulted in a final determination by the officer or the board to suspend or revoke the permit, and all appeals have been exhausted or the time for appeals from that final determination has been exhausted.
(c) The annual extension of a permit's expiration date pursuant to subdivision (b) does not constitute permit issuance, renewal, reopening, amendment, or any other action subject to the requirements specified in Title V.

REQUIREMENTS FOR PERMIT ISSUANCE - 42301

A permit system established pursuant to Section 42300 shall do all of the following:
(a) Ensure that the article, machine, equipment, or contrivance for which the permit was issued does not prevent or interfere with the attainment or maintenance of any applicable air quality standard.
(b) Prohibit the issuance of a permit unless the air pollution control officer is satisfied, on the basis of criteria adopted by the district board, that the

article, machine, equipment, or contrivance will comply with all of the following:

(1) All applicable orders, rules, and regulations of the district and of the state board.

(2) All applicable provisions of this division.

(c) Prohibit the issuanc of a permit to a Title V source if the Administrator of the Environmental Protection Agency objects to its issuance in a timely manner as provided in Title V. This subdivision is not intended to provide any authority to the Environmental Protection Agency to object to the issuancc of a permit other than that authority expressly granted by Title V.

(d) Provide that the air pollution control officer may issue to a Title V source a permit to operate or use if the owner or operator of the Title V source presents a variance exempting the owner or operator from Section 41701, any rule or regulation of the district, or any permit condition imposed pursuant to this section, or presents an abatement order that has the effect of a variance and that meets all of the requirements of this part pertaining to variances, and the requirements for the issuance of permits to operate are otherwise satisfied. The terms and conditions of any variance or abatement order may be incorporated into the permit as a compliance schedule, to the extent requried by Title V.

(e) Require, upon annual renewal, that each permit be reviewed to determine that the permit conditions are adequate to ensure compliance with, and the enforceability of, district rules and regulations applicable to the article, machine, equipment, or contrivance for which the permit was issued which were in effect at the time the permit was issued or modified, or which have subsequently been adopted and made retroactively applicable to an existing article, machine, equipment, or contrivance, by the district board and, if the permit conditions are not consistent, require that the permit be revised to specify the permit conditions in accordance with all applicable rules and regulations.

(f) Provide for the reissuance or transfer of a permit to a new owner or operator of an article, machine, equipment, or contrivance. An application for transfer of ownership only, or change in operator only, of any article, machine, equipment, or contrivance whch had a valid permit to operate within the two-year period immediately preceding the application is a temporary permit to operate. Issuance of the final permit to operate shall be conditional upon a determination by the district that the criteria specified in subdivisions (b) and (e) are met, if the permit was not surrendered as a condition to receiving emission reduction credits pursuant to banking or permitting rules of the district. However, under no circumstances shall the criteria specify that a change of ownership or operator alone is a basis for requiring more stringent emission controls or operating conditions than would otherwise apply to the article, machine, equipment, or contrivance.

PERMIT APPROVAL: POWERS AND DUTIES OF AIR POLLUTION CONTROL OFFICER - 42301.6

(a) Prior to approving an application for a permit to construct or modify a source which emits hazardous air emissions, which source is located within 1,000 feet from the outer boundary of a schoolsite, the air pollution control officer shall prepare a public notice in which the proposed project or modification for which the application for a permit is made is fully described. The notice may be prepared whether or not the material is or would be subject to subdivision (a) of Section 25536, if the air pollution control officer determines and the administering agency concurs that hazardous air emissions of the material may result from an air release, as defined by Section 44303. The notice may be combined with any other notice on the project or permit which is required by law.

(b) The air pollution control officer shall, at the permit applicant's expense, distribute or mail the public notice to the parents or guardians of children enrolled in any school that is located within one-quarter mile of the source and to each address within a radius of 1,000 feet of the proposed new or modified source at least 30 days prior to the date final action on the application is to be taken by the officer. The officer shall review and consider all comments received during the 30 days after the notice is distributed, and shall include written responses to the comments in the permit application file prior to taking final action on the application.

(1) Notwithstanding Section 49073 of the Education Code, or any other provision of law, the information necessary to mail notices requried by this section shall be made available by the school district to the air pollution control officer.

(2) Nothing in this subdivision precludes, at the discretion of the air pollution control officer and with permission of the school, the distribution of the notices to the children to be given to their parents or guardians.

(c) Notwithstanding subdivision (b), an air pollution control officer may require the applicant to distribute the notice if the district had such a rule in effect prior to January 1, 1989.

(d) The requirements for public notice pursuant to subdivision (b) or a district rule in effect prior to January 1, 1989, are fulfilled if the air pollution control officer or applicant responsible for giving the notice makes a good faith effort to follow the procedures prescribed by law for giving the notice, and, in these circumstances, failure of any person to receive the notice shall not affect the validity of any permit subsequently issued by the officer.

(e) Nothing in this section shall be deemed to limit any existing authority of any district.

(f) An applicant for a permit shall certify whether the proposed source or modification is located within 1,000 feet of a schoolsite. Misrepresentation of this fact may result in the denial of a permit.

(g) The notice requirements of this section shall not apply if the air pollution control officer determines that the application to construct or modify a source will result in a reduction or equivalent amount of air contaminants, as defined in Section 39013, or whch are hazardous air emissions.

(h) As used in this section:

(1) "Hazardous air emissions" means emissions into the ambient air of air contaminants which have been identified as a toxic air contaminant by the state board or by the air pollution control officer for the jurisdiction in which the project is located. As determined by the air pollution control officer, hazardous air emissions also means emissions into the ambient air from any substances identified in subdivisions (a) to (f), inclusive, of Section 44321 of the Health and Safety Code.

(2) "Acutely hazardous material" means any material defined pursuant to subdivision (a) of Section 25532.

AIR CONTAMINANTS, THREATENED RELEASE - 42301.7

(a) If the air pollution control officer determines there is a reasonably foreseeable threat of a release of an air contaminant from a source within 1,000 feet of the boundary of a school that would result in a violation of Section 41700 and impact persons at the school, the officer shall, within 24 hours, notify the administering agency and the fire department having jurisdiction over the school.

(b) The administering agency may, in responding to a reasonably foreseeable threat of a release, do any of the following:

(1) Review the facility's risk management and prevention plan prepared pursuant to Section 25534 to determine whether the program should be modified, and, if so, require submission of appropriate modifications. Notwithstanding any other provision of law, the administering agency may order modification and implementation of a revised risk management and prevention plan at the earliest feasible date.

(2) If the facility has not filed a risk management and prevention plan with the administering agency, require the preparation and submission of a plan to the administering agency pursuant to Section 25534. Notwithstanding any other provision of law, the administering agency may require the filing of a risk management and prevention plan and its implementation at the earliest

feasible date.
(c) The air pollution control officer may, in responding to a reasonably foreseeable threat of a release, do any of the following:
(1) If necessary, issue an immediate order to prevent the release or mitigate the reasonably foreseeable threat of a release in violation of Section 41700 pending a hearing pursuant to Section 42450 when there is a substantial probability of an injury to persons at a school resulting from a release that makes it reasonably necessary to take immediate action to prevent, reduce, or mitigate that injury. The officer may not issue such an order unless there is written concurrence to issue the order by a representative of the administering agency.
(2) Apply to the district board for issuance of an order for abatement pursuant to Section 42450.
(d) Nothing in this section limits any existing authority of any district.

AIR CONTAMINANT DISCHARGE: INFORMATION DISCLOSURE - 42303

An air pollution control officer, at any time, may require from an applicant for, or the holder of, any permit provided for by the regulations of the district board, such information, analyses, plans, or specifications which will disclose the nature, extent, quantity, or degree of air contaminants which are, or may be, discharged by the source for which the permit was issued or applied.

FALSE STATEMENTS IN PERMIT APPLICATIONS - 42303.5

No person shall knowingly make any false statement in any application for a permit, or in any information, analyses, plans, or specifications submitted in conjunction with the application or at the request of the air pollution control officer.

PERMIT SUSPENSION [FAILURE TO SUPPLY INFORMATION] - 42304

If, within a reasonable time, the holder of any permit issued by a district board willfully fails and refuses to furnish the information, analyses, plans, or specifications requested by the district air pollution control officer, such officer may suspend the permit. Such officer shall serve notice in writing of such suspension and the reasons therefor on the permittee.

GENERAL VIOLATIONS, CRIMINAL - 42400

(a) Except as otherwise provided in Section 42400.1, 42400.2, or 424003, any person who violates this part, or any rule, regulation, permit, or order of the state board or of a district, including a district hearing board, adopted pursuant to Part 1 (commencing with Section 39000) to Part 4 (commencing with Section 41500), inclusive, is guilty of a misdemeanor and is subject to a fine of not more than one thousand dollars ($1,000) or imprisonment in the county jail for not more than six months, or both.
(b) If a violation under subdivision (a) with regard to the failure to operate a vapor recovery system on a gasoline cargo tank is directly caused by the actions of an employee under the supervision of, or of any independent contractor working for, any person subject to this part, the employee or independent contractor, as the case may be, causing the violation is guilty of a misdemeanor and is punishable as provided in subdivision (a). That liability shall not extend to the person employing the employee or retaining the independent contractor, unless that person is separately guilty of an action that violates this part.
(c) The recovery of civil penalties pursuant to Section 42402, 42402.1, 42402.2, or 42402.3 precludes prosecution pursuant to this section for the same offense. When a district refers a violation to a prosecuting agency, the filing of a criminal complaint is grounds requiring the dismissal of any civil

action brought pursuant to this article for the same offense.
(d) Each day during any portion of which a violation of subdivision (a) occurs is a separate offense.

NEGLIGENCE, CRIMINAL - 42400.1

(a) Any person who negligently emits an air contaminant in violation of any provision of this part or any rule, regulation, permit, or order of the state board or of a district pertaining to emission regulations or limitations is guilty of a misdemeanor and is subject to a fine of not more than fifteen thousand dollars ($15,000) or imprisonment in the county jail for not more than nine months, or both.
(b) Any person who owns or operates any source of air contaminants in violation of Section 41700 which causes actual injury, as defined in paragraph (2) of subdivision (d) of Section 42400.2, to the health or safety of a considerable number of persons or the public is guilty of a misdemeanor and is punishable as provided in subdivision (a).
(c) Each day during any portion of which a violation occurs is a separate offense.
(d) The recovery of civil penalties pursuant to Section 42402, 42402.1, 42402.2, or 42402.3 precludes prosecution pursuant to this section for the same offense. When a district refers a violation to a prosecuting agency, the filing of a criminal complaint is grounds requiring the dismissal of any civil action brought pursuant to this article for the same offense.

DOCUMENT FALSIFICATION OR FAILURE TO TAKE CORRECTIVE ACTION, CRIMINAL - 42400.2

(a) Any person who emits an air contaminant in violation of any provision of this part, or any order, rule, regulation, or permit of the state board or of a district pertaining to emission regulations or limitations, and who knew of the emission and failed to take corrective action within a reasonable period of time under the circumstances, is guilty of a misdemeanor and is subject to a fine of not more than twenty-five thousand dollars ($25,000) or imprisonment in the county jail for not more than one year, or both.

(b) For purposes of this section, "corrective action" means the termination of the emission violation or the grant of a variance from the applicable order, rule, regulation, or permit pursuant to Article 2 (commencing with Section 42350). If a district regulation regarding process upsets or equipment breakdowns would allow continued operation of equipment which is emitting air contaminants in excess of allowable limits, compliance with that regulation is deemed to be corrective action.

(c) Any person who, knowingly and with intent to deceive, falsifies any document required to be kept pursuant to any provision of this part, or any rule, regulation, permit, or order of the state board or of a district, is guilty of a misdemeanor and is punishable as provided in subdivision (a).

(d) (1) Any person who owns or operates any source of air contaminants in violation of Section 41700 which causes actual injury to the health or safety of a considerable number of persons or the public, and who knew of the emission and failed to take corrective action within a reasonable period of time under the circumstances, is guilty of a misdemeanor and is punishable as provided in subdivision (a).

(2) As used in this subdivision, "actual injury" means any physical injury which, in the opinion of a licensed physician and surgeon, requires medical treatment involving more than a physical examination.

(e) Each day during any portion of which a violation occurs constitutes a separate offense.

(f) The recovery of civil penalties pursuant to Section 42402, 42402.1, 42402.2, or 42402.3 precludes prosecution pursuant to this section for the same offense. When a district refers a violation to a prosecuting agency, the filing of a criminal complaint is grounds requiring the dismissal of any civil action brought pursuant to this article for the same offense.

WILLFUL INTENT, CIVIL - 42400.3

(a) Any person who willfully and intentionally emits an air contaminant in violation of any provision of this part or any rule, regulation, permit, or order of the state board or of a district, pertaining to emission regulations or limitations is guilty of a misdemeanor and is subject to a fine of not more than fifty thousand dollars ($50,000) or imprisonment in the county jail for not more than one year, or both.
(b) The recovery of civil penalties pursuant to Section 42402, 42402.1, 42402.2, or 42402.3 precludes prosecution pursuant to this section for the same offense. When a district refers a violation to a prosecuting agency, the filing of a criminal complaint is grounds requiring the dismissal of any civil action brough pursuant to this article for the same offense.
(c) Each day during any portion of which a violation occurs constitutes a separate offense.

VIOLATING ORDER OF ABATEMENT, CIVIL 42401

Any person who intentionally or negligently violates any order of abatement issued by a district pursuant to Section 42450, by a hearing board pursuant to Section 42451, or by the state board pursuant to Section 41505 is liable for a civil penalty of not more than twenty-five thousand dollars ($25,000) for each day in which the violation occurs.

GENERAL VIOLATIONS, CIVIL - 42402

(a) Except as otherwise provided in subdivision (b) or in Section 42402.1, 42402.2, or 42402.3, any person who violates this part, any order issued pursuant to Section 42316, or any rule, regulation, permit, or order of a district, including a district hearing board, or of the state board issued pursuant to Part 1 (commencing with Section 39000) to Part 4 (commencing with Section

41500), inclusive, is strictly liable for a civil penalty of not more than one thousand dollars ($1,000).

(b) (1) Any person who violates any provision of this part, any order issued pursuant to Section 42316, or any rule, regulation, permit, or order of a district, including a district hearing board, or of the state board issued pursuant to Part 1 (commencing with Section 39000) to Part 4 (commencing with Section 41500), inclusive, is strictly liable for a civil penalty of not more than ten thousand dollars ($10,000).

(2) Where a civil penalty in excess of one thousand dollars ($1,000) for each day in which the violation occurs is sought, there is no liability under this subdivision if the person accused of the violation alleges by affirmative defense and establishes that the violation was caused by an act which was not the result of intentional or negligent conduct. In a district in which a Title V permit program has been fully approved, this paragraph shall not apply to a violation of federally enforceable requirements that occurs at a Title V source.

(c) Each day during any portion of which a violation occurs is a separate offense.

NEGLIGENCE OR ACTUAL INJURY, CIVIL - 42402.1

(a) Any person who negligently emits an air contaminant in violation of this part or any rule, regulation, permit, or order of the state board or of a district pertaining to emission regulations or limitations is liable for a civil penalty of not more than fifteen thousand dollars ($15,000).

(b) Any person who owns or operates any source of air contaminants in violation of Section 41700 which causes actual injury, as defined in paragraph (2) of subdivision (d) of Section 42400.2, to the health or safety of a considerable number of persons or the public is liable for a civil penalty as provided in subdivision (a).

(c) Each day during any portion of which a violation occurs is a separate offense.

DOCUMENT FALSIFICATION OR FAILURE TO TAKE CORRECTIVE ACTION, CIVIL - 42402.2

(a) Any person who emits an air contaminant in violation of any provision of this part, or any order, rule, regulation, or permit of the state board or of a district pertaining to emission regulations or limitations, and who knew of the emission and failed to take corrective action, as defined in subdivision (b) of Section 42400.2, within a reasonable period of time under the circumstances, is liable for a civil penalty, of not more than twenty-five thousand dollars ($25,000).
(b) Any person who, knowingly and with intent to deceive, falsifies any document required to be kept pursuant to any provision of this part, or any rule, regulation, permit, or order of the state board or of a district, is subject to the same civil penalty as provided in subdivision (a).
(c) Any person who owns or operates any source of air contaminants in violation of Section 41700 which causes actual injury , as defined in paragraph (2) of subdivision (d) of Section 42400.2, to the health or safety of a considerable number of persons or the public, and who knew of the emission and failed to take corrective action, as defined in subdivision (b) of Section 42400.2, within a reasonable period of time under the circumstances, is subject to a civil penalty as provided in subdivision (a).
(d) Each day during any portion of which a violation occurs is a separate offense.

GENERAL VIOLATIONS, ADMINISTRATIVE CIVIL [ADMINISTRATIVE PENALTIES] - 42402.5

In addition to any civil and criminal penalties prescribed under this article, a district may impose administrative civil penalties for a violation of this part, or any order, permit, rule, or regulation of the state board or of a district, including a district hearing board, adopted pursuant to Part 1 (commencing with Section 39000) to Part 4 (commencing with Section 41500), inclusive, if the district board has adopted rules and regulations specifying procedures for the imposition and amounts of these penalties. No administrative civil penalty levied pursuant to this section may exceed five hundred dollars ($500) for each violation. However, nothing in this section is intended to restrict the authority of a district to negotiate mutual settlements under any other penalty provisions of law which exceeds five hundred dollars ($500).

RECOVERY OF CIVIL PENALTIES [PROCEDURES/CONSIDERATIONS] - 42403

(a) The civil penalties prescribed in Sections 39674, 42401, 42402, 42402.1, 42402.2, and 42402.3 shall be assessed and recovered in a civil action brought in the name of the people of the State of California by the Attorney General, by any district attorney, or by the attorney for any district in which the violation occurs in any court of competent jurisdiction.
(b) In determining the amount assessed, the court, or in reaching any settlement, the district, shall take into consideration all relevant circumstances, including, but not limited to, the following:
(1) The extent of harm caused by the violation.
(2) The nature and persistence of the violation.
(3) The length of time over which the violation occurs.
(4) The frequency of past violations.
(5) The record of maintenance.
(6) The unproven or innovative nature of the control equipment.
(7) Any action taken by the defendant, including the nature, extent, and time of response of the cleanup and construction undertaken, to mitigate the violation.
(8) The financial burden to the defendant.

STATUTE OF LIMITATIONS FOR CIVIL ACTIONS - 42404.5

Any limitation of time applicable to actions brought pursuant to Section 42403 shall not commence to run until the offense has been discovered, or could reasonably have been discovered.

300 THEORY AND DESIGN

This chapter of the manual is written primarily for air pollution control district inspectors. The reader is provided with a basic understanding of the particulate collection process using fabric filters (baghouses). Various bag designs, filtration designs, bag cleaning designs, auxiliary equipment and instrumentation are then described.

Baghouse operators may be interested in the information about and comparisons of various fabric types, presented in section 303.

301 COLLECTION MECHANISMS

Particles are collected on a filter by a combination of several mechanisms. The most important here are impaction, direct interception and diffusion. In collection by impaction, the particles in the gas stream have too much inertia to follow the gas streamlines around the fiber and are impacted on the fiber surface.

Interception

Impaction

In the case of direct **interception** the particles have less inertia and barely follow the gas streamlines around the fiber. If the distance between the center of the particle and the outside of the fiber is less than the particle radius, the particle will graze or hit the fiber and be "intercepted." **Impaction** and direct interception mechanisms account for 99% of the collection of particles greater than 1 micrometer (µm) aerodynamic diameter in fabric filter systems.

Diffusion

The third collection mechanism is that of **diffusion**. In diffusion, small particles are affected by collisions on a molecular level. Particles less than 0.1 µm aerodynamic diameter have individual or random motion. The particles do not necessarily follow the gas streamlines, but move randomly throughout the fluid. This is known as Brownian motion. The particles may have a different velocity than the fluid and at some point could come in contact with the fiber and be collected.

The above three collection mechanisms are illustrated in figure 301.1 on the next page.

Agglomeration

Other collection mechanisms such as gravitational settling, **agglomeration**, and electrostatic attraction may contribute slightly to particle collection. Large particles may be overcome by the force of gravity and settle in the hopper. Particles can agglomerate or grow in size and then be more easily collected by

Electrostatic Attraction

the fibers. Some particles have a small **electrostatic** charge and can be attracted to a material of opposite charge. Electrostatic charges could, on the other hand, have a reverse affect on collection if the charges of the particles and fiber are the same. Electrostatic charges can be particularly useful for the capture of particles in the submicron range. The use of a selected fiber material or a specially coated material may enhance particle capture (Frederick, 1974). Different materials will develop electrostatic charges of varying degree and sign.

Gravitational Settling

Particles also are collected by **gravitational settling**. Relatively large particles are overcome by the force of gravity and fall into the baghouse hopper. This force is particularly important when dust-laden gas enters the baghouse through a hopper inlet.

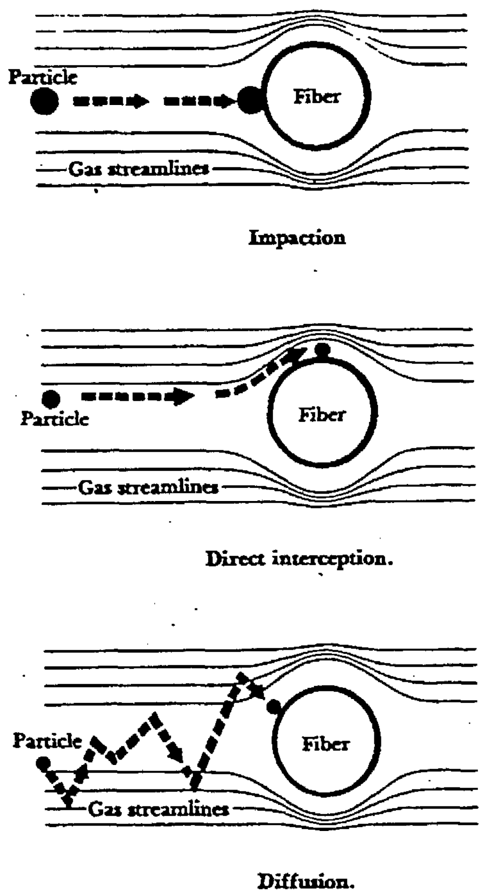

Figure 301.1 Various Particle Collection Mechanisms [1]

302 BAGHOUSE DESIGN TYPES

A baghouse (see figure 302.1) consists of the following component systems:

- filter medium and support
- filter cleaning device
- collection hopper
- shell
- fan

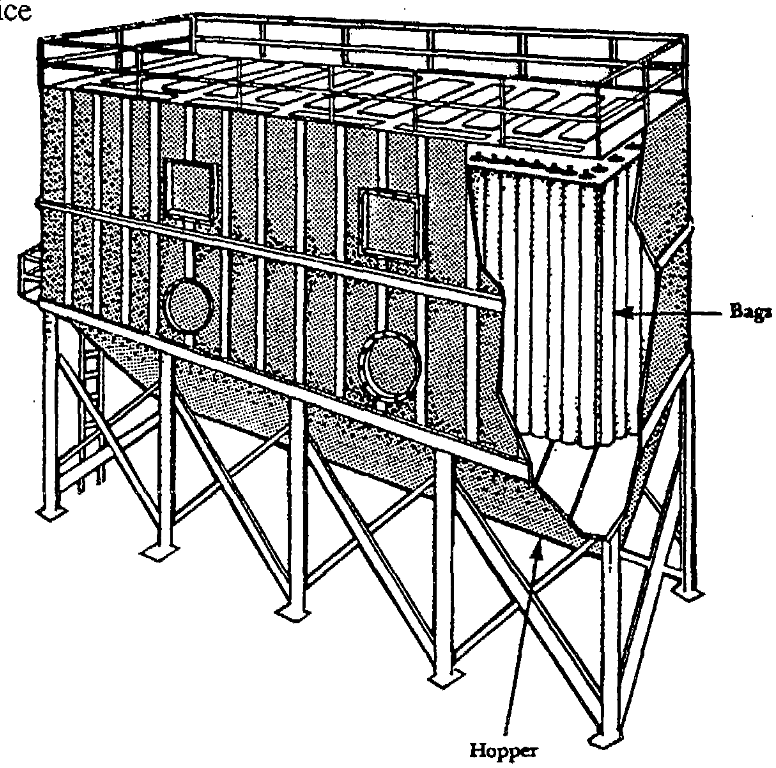

Figure 302.1 Typical Baghouse [1]

There are many different ways to classify a baghouse. Some of the categories that can be used when describing a baghouse are:

- bag design (shape, size);
- fan location (before or after the baghouse);-
- method of dust collection on bag (inside, outside);
- direction of gas flow in baghouse;
- method of cleaning the bags;
- fabric type used in bags.

The following subsections describe the main baghouse design types.

302.1 BAG DESIGNS

Tubes

The particle collection surface is composed of the filtering material and a support structure. Most U.S. baghouse designs employ long cylindrical **tubes** that contain felted fabric or woven cloth as the filtering medium. The cloth can be supported at the top and bottom of the bag by metal rings or clasps, or by an internal cage that completely supports the entire bag.

Dust is collected on either the inside or outside of the fabric material depending on the baghouse design.

Envelope Filters

Some European baghouse designs employ an **envelope filter** arrangement. The envelope filter consists of felted or woven fabric supported by a metal retaining cage. The metal cage keeps the fabric taut as the dust filters through and collects on the outside of the material. Clean air passes out the open end of the envelope. The envelope baghouse consists of compartments that contain envelopes of fabric mounted on frames and attached to the walls of the collector. Figure 302.2 shows an envelope baghouse.

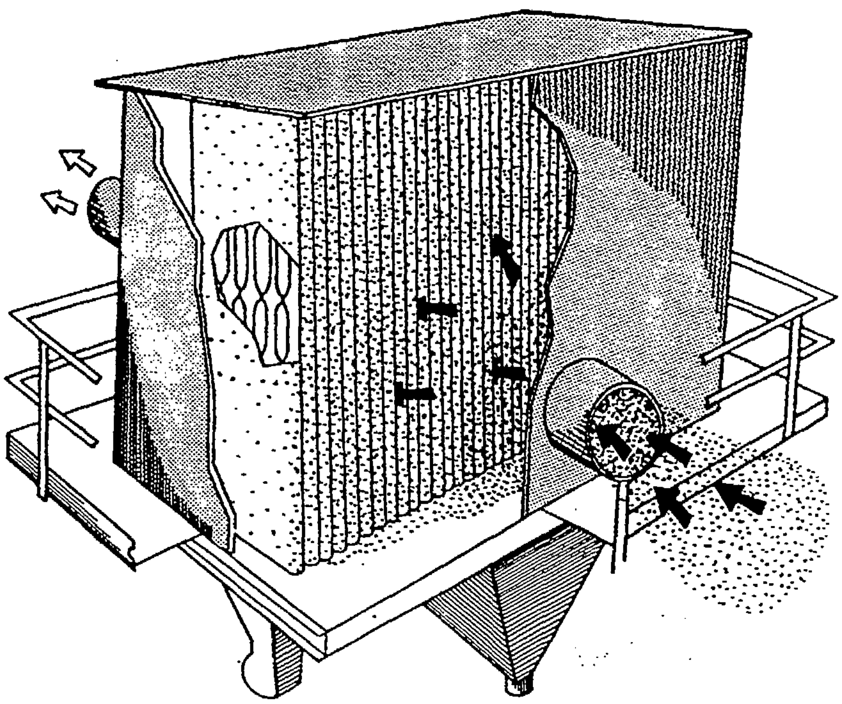

Figure 302.2 Envelope Baghouse [1]

Cartridge Filters

More recently, cartridge filters (see figure 302.3) have been used for filtering particulate matter from small industrial processes. The **cartridge filters** are similar to truck filters and are approximately 2 ft long. Dust is collected on the outside of the cartridge while clean air flows on through the center. Cartridge systems operate similarly to a baghouse that uses bag tubes. Cartridge baghouses are usually used on smaller industrial processes handling exhaust flow rates less than 50,000 cfm.

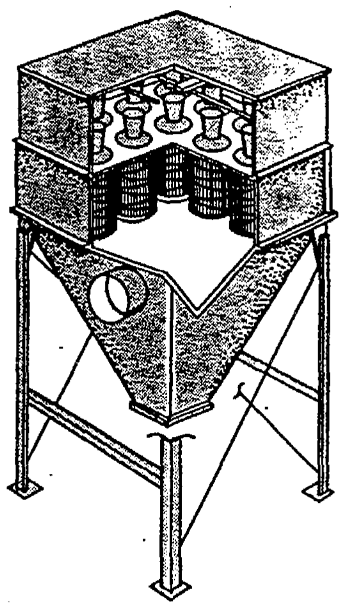

Figure 302.3 Cartridge Baghouse [1]

302.2 POSITIVE AND NEGATIVE PRESSURE BAGHOUSES

Dirty gas is either pushed or pulled through the baghouse by a fan. When the dust laden gas is pushed through the baghouse the collector is called a positive pressure baghouse. Vendors can construct positive pressure baghouses with a weaker support structure since the positive pressure will counterbalance the atmospheric pressure on the baghouse shell. Limitations, however, do exist since the fan is located on the dirty side of the system. Premature deterioration of fan blades, bearings, and duct work can occur in this configuration. This is very important in terms of operation and maintenance of the baghouse. The fan is an integral component; if it becomes worn out, it will cause a shutdown of the entire baghouse.

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Positive pressure baghouses usually have short stubby stacks or outlets at the top of the baghouse called roof monitors. This is a problem when stack testing for determining the compliance status of the source. In this case a high volume sampler can be inserted in the stack opening or into the baghouse compartment for compliance testing. Positive pressure systems are used when process streams contain low moisture content and low dust concentration of nonabrasive dusts. Positive and negative pressure baghouses are shown in figure 302.4.

When the fan is on the downstream side of the baghouse, the dirty gas is pulled through the baghouse and the collector is called a negative pressure baghouse. The structure of a negative pressure baghouse must be reinforced because of the suction on the baghouse shell. The construction costs will therefore be higher than for positive pressure systems. Since the baghouse housing is under negative pressure, there are no pressure leaks, so general housekeeping in the immediate vicinity is minimized. The wear and tear on the fan is much less than with positive systems since the particulate matter is removed by the bags before it can enter the fan. This may be the overriding factor in selecting a negative pressure baghouse. Negative pressure systems are used when process streams contain high moisture content, corrosive gases, and/or high concentrations of abrasive dusts.

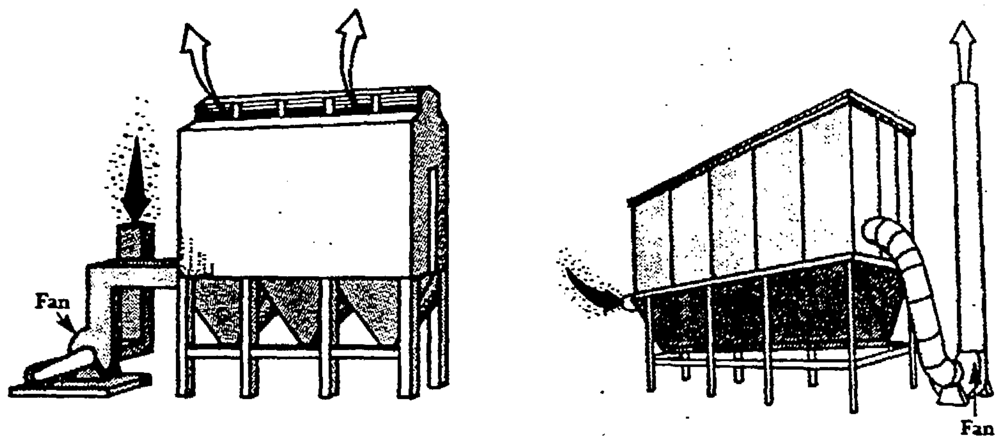


Figure 302.4 Positive and Negative Pressure Baghouses [1]

302.3 FILTRATION DESIGNS

There are two filtration designs used in baghouses: interior filtration and exterior filtration. In baghouses using interior filtration, particles are collected on the inside of the bag. The dust laden gas enters through the bottom of the collector and is directed inside the bag by diffuser vanes or baffles and a cell plate. The cell plate separates the clean gas section from the baghouse inlet. The particles are filtered by the bag and clean air exits through the outside of the bag as shown in figure 302.5.

For interior filtration the bags may be held at the top by a spring and a metal cap. This arrangement is used for reverse air cleaning baghouses.

Bags for shaker cleaning baghouses (also interior filtration) are attached at the top by a hook. Shaker and reverse air cleaning will be discussed in more detail in later sections.

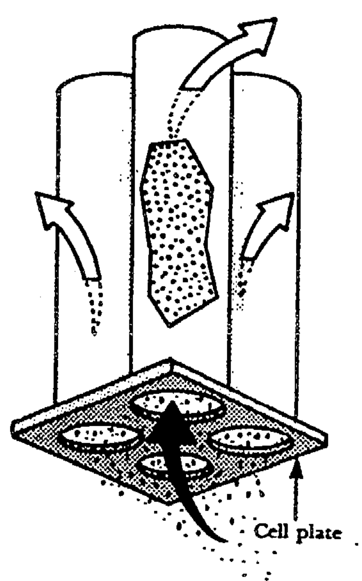


Figure 302.5 Interior Filtration [1]

In exterior filtration systems, dust is collected on the outside of the bags. The filtering process goes from the outside of the bag to the inside with clean gas exiting through the inside of the bag, as shown in figure 302.6. Consequently, some type of bag support is necessary, such as an internal bag cage or rings sewn into the bag fabric. Bags are attached at the top to a tube sheet and are closed at the bottom by an end cap.

The dust-laden gas inlet position for both filtration systems often depends on the baghouse model and manufacturer. If the gas enters the top of the unit, a downwash of gas occurs which tends to clean the bags somewhat while the bags are filtering. This usually allows slightly higher gas volumes to be filtered through the baghouse before cleaning is required. If the gas enters the bottom of the unit, the inlet is positioned at the very top part of the dust hopper. Bottom or hopper inlets are easier to design and manufacture structurally than are the top inlets. However, when using hopper inlets, vendors must carefully design gas flows to avoid dust reentrainment from the hopper.

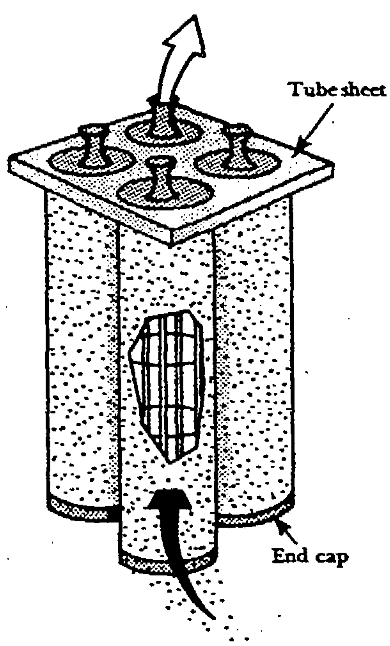


Figure 302.6 Exterior Filtration [1]

302.4 FABRIC CLEANING TYPES

Two basic sequences are used for bag cleaning: intermittent, or periodic cleaning; and continuous filter cleaning.

Intermittent Cleaning

Intermittently cleaned baghouses consist of a number of compartments or sections. One compartment at a time is removed from service and cleaned on a regular rotation basis. The dirty gas stream is diverted from the compartment being cleaned to the other compartments in the baghouse, so it is not necessary to shut down the process. Occasionally, the baghouse is very small and consists of a single compartment. The flow of dirty air into the baghouse is stopped during bag cleaning. These small single compartment baghouses are used on batch processes that can be shut down for bag cleaning.

Continuous Cleaning

Continuously cleaned baghouses are fully automatic and can constantly remain on-line for filtering. The filtering process is momentarily interrupted by a blast of compressed air that cleans the bag, called pulse jet cleaning. In continuous cleaning, a row of bags is always being cleaned somewhere in the baghouse. The advantage of continuous cleaning is that it is not necessary to take the baghouse out of service. Large continuous cleaning baghouses are built with compartments to help prevent total baghouse shutdown for bag maintenance and failures to the compressed air cleaning system or hopper conveyors. This allows the baghouse operator to take one compartment off-line to perform necessary maintenance.

A number of cleaning mechanisims are used to remove caked particles from bags. The three most common are shaking, reverse air, and pulse jet. Another mechanism called blow ring or reverse jet is normally not used in modern bag cleaning systems. Shaker, reverse air, sonic and reverse jet mechanisms are intermittent, while pulse jet cleaning is continuous.

302.4.1 Shaking

Manual Shaking

Shaking can be done manually, but is usually performed mechanically in industrial-scale baghouses. Small baghouses handling exhaust streams less than 500 cfm are frequently cleaned by hand levers. However, thorough cleaning is rarely achieved since a great amount of effort must be used for several minutes to remove dust cakes from the bags. In addition, these small units do not usually have a manometer installed on them to give pressure drop readings across the baghouse. These readings are used to determine when bag cleaning is necessary. Therefore, manual shaker baghouses are not recommended for use in controlling particulate emissions.

Mechanical shaking is accomplished by using a motor that drives a shaft to move a rod connected to the bags. It is a low energy process that gently shakes the bags to remove deposited particles. The shaking motion and speed depends upon the vendor's design and the composition of dust deposited on the bag. The shaking motion can be either in a horizontal or vertical direction, with the horizontal being the most often used. The tops of the bags in shaker baghouses are sealed or closed and supported by a hook or a clasp. Bags are open at the bottom and attached to a cell plate. The bags are shaken at the bottom by moving the cell plate or at the top by moving the frame where the bags are attached (see figure 302.7). This causes the bags to ripple and release the dust. The flow of dirty gas is stopped during the cleaning process. The duration of the cleaning cycle is usually 30 seconds to a few minutes. Therefore, the baghouse must be compartmentalized to be useable on a continuous basis. Shaker baghouses usually use **interior filtration** (dust collected on the inside of the bags). Figure 302.8 shows a cutaway view of a shaker baghouse. Figure 302.9 illustrates shaker cleaning action.

Interior Filtration

Sticky Dust

Shaking should not be used when collecting **sticky dusts**. The forces needed for removing sticky dust can cause the bag to be torn or ripped.

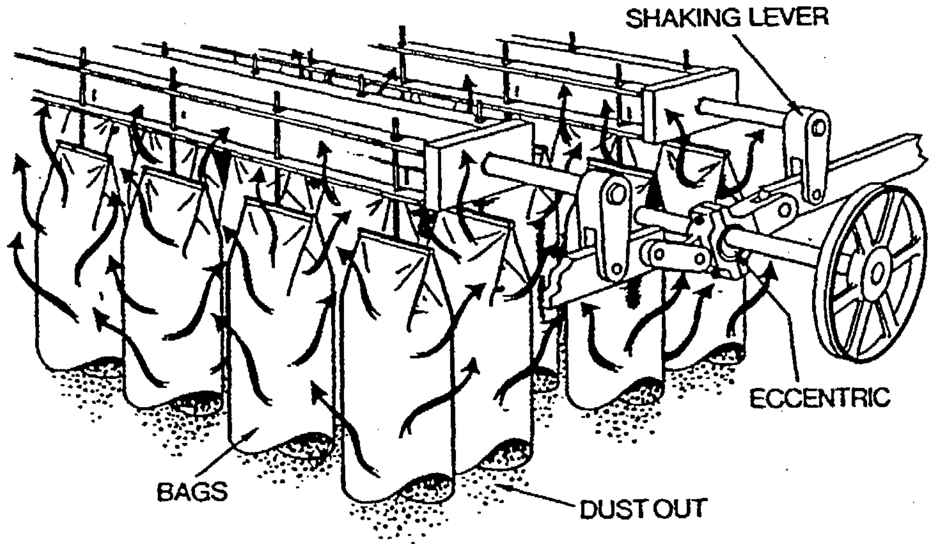


Figure 302.7 Typical Shaking Mechanism [2]

Bag Wear

Bag wear on the whole can be a problem at the bottom of the bag which is attached to the cell plate; the greatest wear is usually at the top of the bag where the support loop attaches to the bag. Proper shaking frequency is therefore important to prevent premature bag failure.

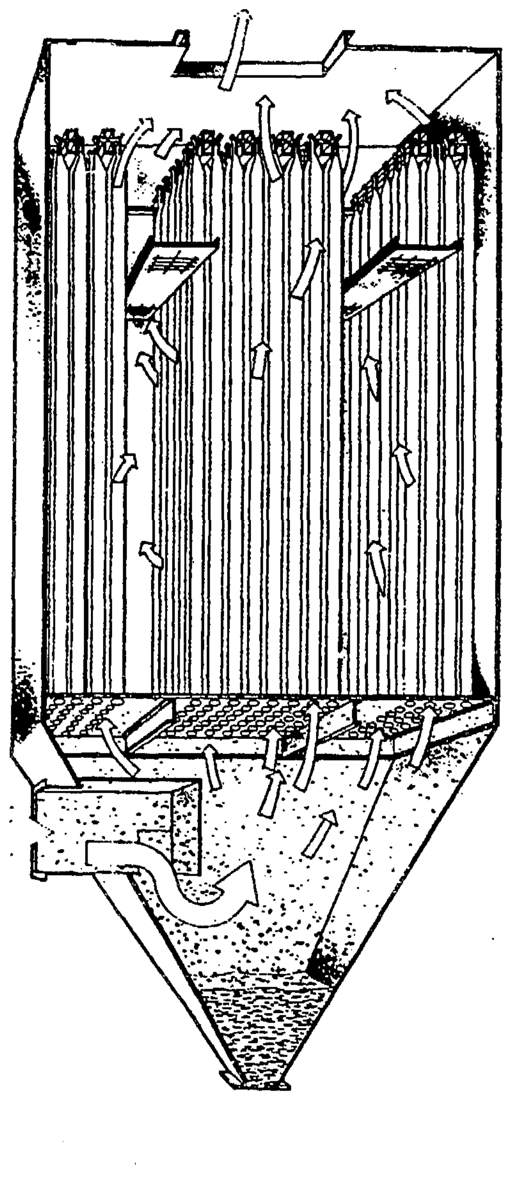


Figure 302.8 Cutaway View of a Shaker Baghouse [3]

The frequency of the cleaning depends on the type of dust, the concentration, and the pressure drop across the baghouse. The baghouse usually has two or more compartments to allow one compartment to be shut down for cleaning.

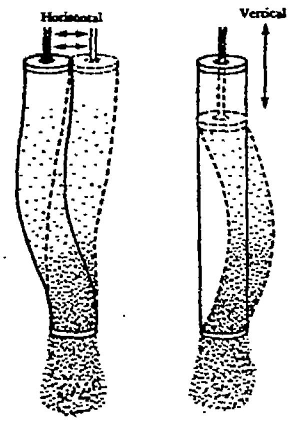


Figure 302.9 Shaker Cleaning Action [1]

Sonic Vibration

In a few systems, bag cleaning is accomplished by sonic vibration. A sound generator is used to produce a low frequency sound that causes the bags to vibrate (see figure 302.10). The noise level produced by the generator is barely discernable outside the baghouse. This type of cleaning, however, is not used on many newer baghouse systems. **Sonic cleaning** is usually used to augment either shaker-type cleaning or reverse air cleaning.

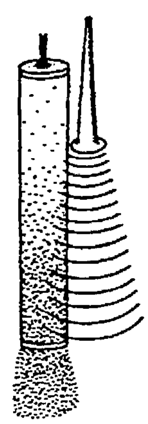


Figure 302.10 Sonic Vibration Cleaning Action [1]

302.4.2 Reverse Air

Reverse air, the simplest cleaning mechanism, is accomplished by stopping the flow of dirty gas into the compartment and backwashing the compartment with a low pressure flow of air. Dust is removed by merely allowing the bags to collapse, thus causing the dust cake to break and fall into the hopper. The cleaning action is very gentle, allowing the use of less abrasion resistant fabrics such as Fiberglas®. Reverse air cleaning is generally used for cleaning woven fabrics. Cleaning frequency varies from 30 minutes to several hours, depending on the inlet dust concentration. The cleaning duration is approximately 10 to 30 seconds; the total time is 1 to 2 minutes including valve opening and closing and dust settling.

Figures 302.11 and 302.12 illustrate different reverse air baghouse designs.

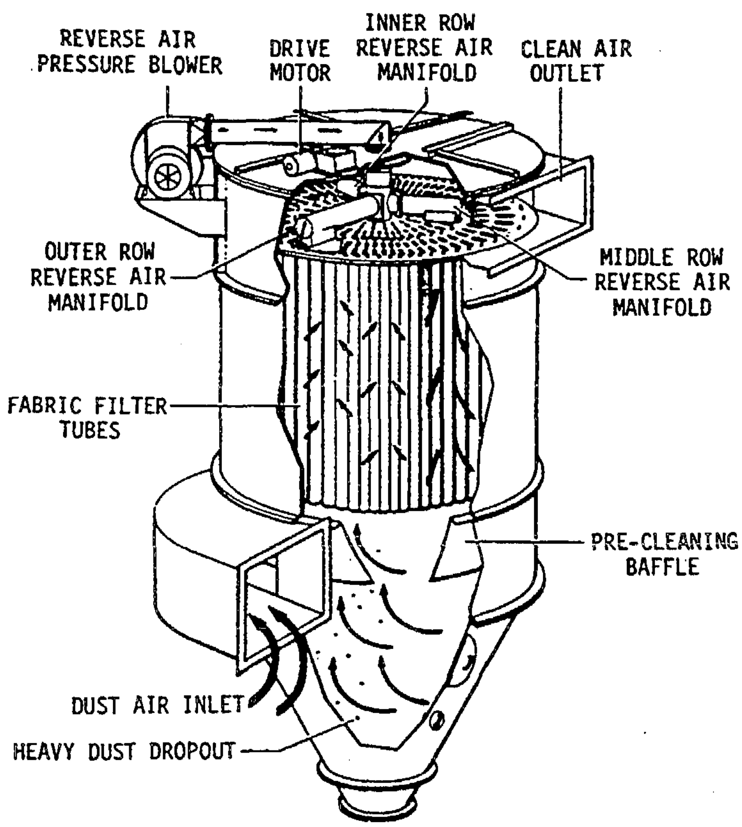


Figure 302.11 Example of a Small Reverse Air Baghouse Design [4]

Compartments

Large Bags

Reverse air cleaning baghouses are usually **compartmentalized** to permit a section to be off-line for cleaning. Dust can be collected on either the inside or outside of the bag. Normally dust is collected on the inside of the bag, the bag being open at the bottom and sealed by a metal cap at the top. Bags are supported by small steel rings sewn to the inside of the bag. The rings are placed every 4 to 18 inches throughout the bag length, depending on the length and diameter of the bag, to prevent complete collapse during the cleaning cycle. Complete collapse of the bag would prevent the dust from falling into the hopper. Reverse air baghouses use very **large bags** (as compared to shaker or pulse jet baghouses) ranging from 8 to18 inches in diameter and from 20 to 40 feet in length.

Cleaning air is supplied by a separate fan which is normally much smaller than the main system fan, since only one compartment is cleaned at a time.

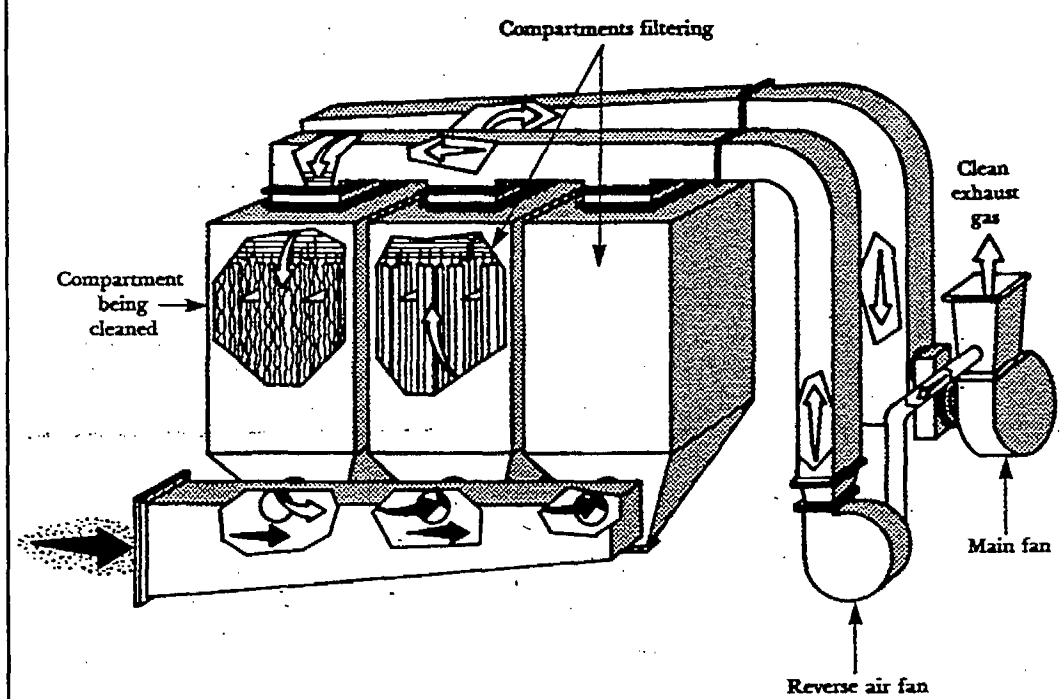


Figure 302.12 Typical Reverse Air Baghouse [1]

302.4.3 Pulse Jet

The third bag cleaning mechanism most commonly used is pulse jet or pressure jet cleaning. Baghouses using pulse jet cleaning make up approximately 40 to 50 percent of the new baghouse installations in the U.S. today. The pulse jet cleaning mechanism uses a high pressure jet of air to remove the dust from the bag. Bags in the baghouse compartment are supported internally by rings or cages. Bags are held firmly in place at the top by clasps and have an enclosed bottom (usually a metal cap). Dust-laden gas is filtered through the bag, depositing dust on the outside surface of the bag. Pulse jet cleaning is used for cleaning bags in an **exterior filtration** system.

Exterior Filtration

The dust cake is removed from the bag by a blast of compressed air injected into the top of the bag tube. The blast of high pressure air stops the normal flow of air through the filter. The air blast develops into a standing or shock wave that causes the bag to flex or expand (see figure 302.13) as the shock wave travels down the bag tube. As the bag flexes, the cake fractures and deposited particles are discharged from the bag. The shock wave travels down and back up the tube in approximately 0.5 second.

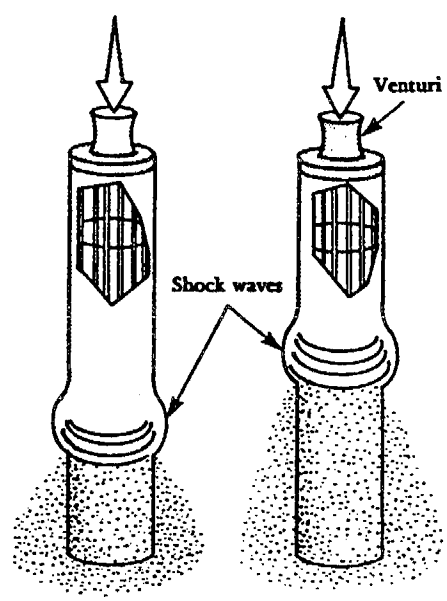


Figure 302.13 Pulse Jet Cleaning Action [1]

300 THEORY AND DESIGN

The blast of compressed air must be strong enough for the shock wave to travel the length of the bag and shatter or crack the dust cake. Pulse jet units use air supplies from a common header which feeds into a nozzle located above each bag. In most baghouse designs, a venturi seated at the top of each bag is used to create a large enough pulse to travel down and up the bag. This occurs in approximately 0.3 to 0.5 sec. The pressures involved are commonly between 60 and 100 psig (414 kPa and 689 kPa). The importance of the venturi is being questioned by some pulse jet baghouse vendors. Some baghouses operate with only the **compressed air** manifold above each bag. Figure 302.14 shows a simple pulse jet collector and its operating components.

Compressed Air

Most pulse jet baghouses use bag tubes that are 4 to 6 in. (10 to 15 cm) in diameter. The length of the bag is usually around 10 to 12 ft (3 to 3.7 m), but can be as long as 25 ft (7.6 m). The shaker and reverse air baghouses use longer bags than the pulse jet units. The bags in these units are 6 to 18 in. (15 to 46 cm) in diameter and up to 40 ft (12 m) in length.

Pulse jet baghouses can also be compartmentalized. In this case it is possible to stop the flow of dirty air into the compartment by using poppet valves located in the clean air plenum. Each compartment is equipped with a single pulse valve that supplies compressed air to the group of bags. During the cleaning cycle the poppet valve closes, stopping the air flow through the compartment. The pulse valve opens for about 0.1 second, supplying a burst of air into the bags for cleaning. The poppet valve then automatically reopens, bringing the compartment back on stream. Alternate compartments are cleaned successively until all the bags in the baghouse have been cleaned. The cleaning cycle in each compartment lasts about four seconds.

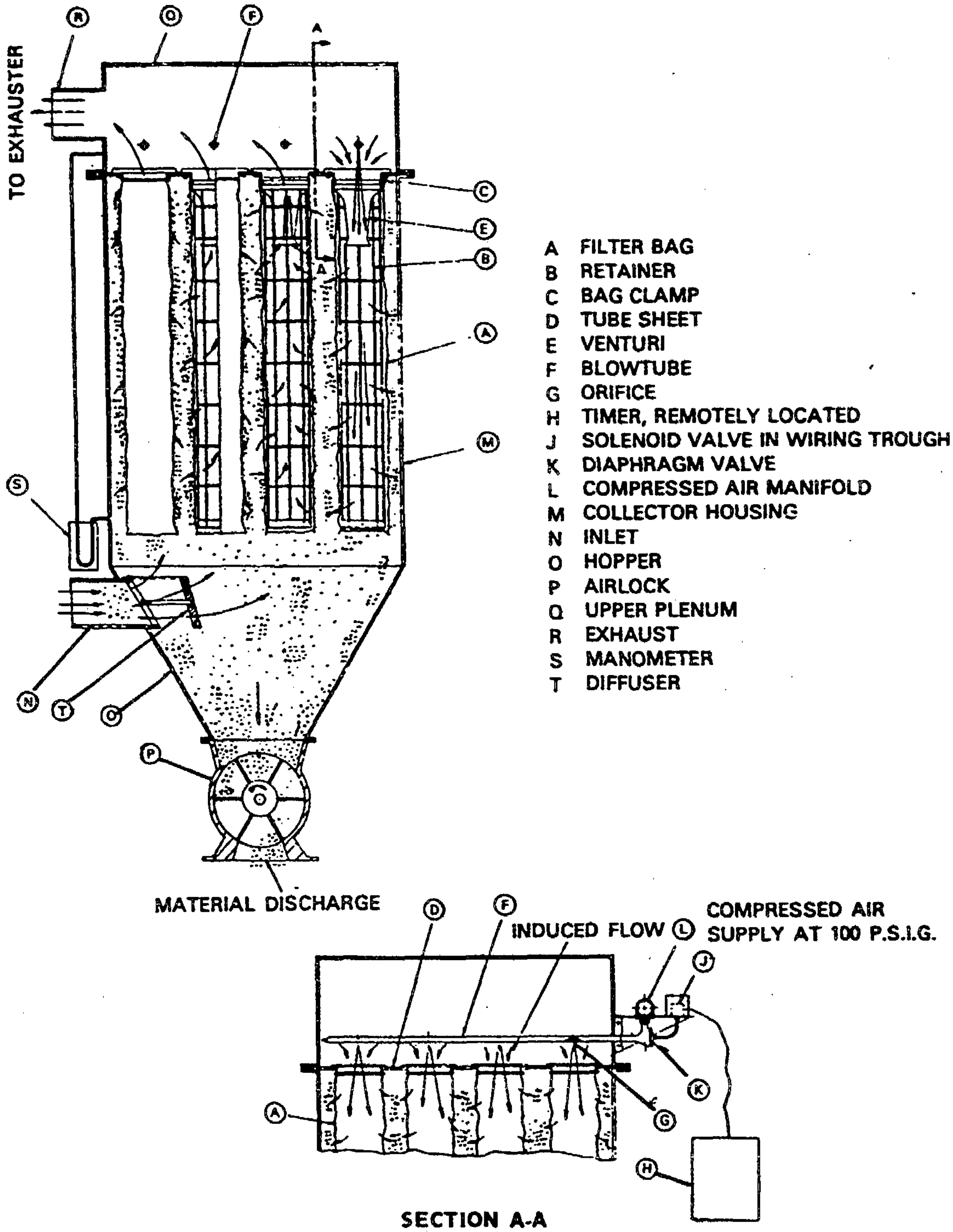
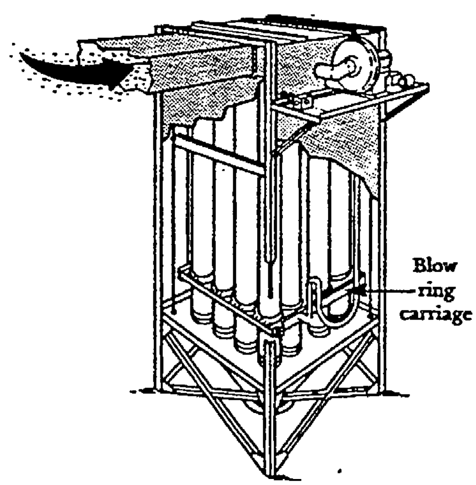


Figure 302.14 Pulse Jet Collector and Operating Components [5]

302.4.4 Reverse Jet or Blow Ring

Another bag cleaning mechanism is reverse jet cleaning using a blow ring. Some older baghouse designs employed this method, but it has lost popularity due to the great number of moving parts inside the baghouse. Blow ring cleaning involves reversing the air flow on each bag (see figure 302.15). This cleaning method does not depend on the collapse of each bag to crack the cake as in the reverse air baghouse. A traveling blow ring carriage moves up and down the bag compartment. Each **ring has a number of slots** where high velocity air jets penetrate the bag tube and dislodge the accumulated dust layer. The expense and complication of the blow ring mechanism (motors, drives, and switches for both ring and fan) limits the applicability of this equipment for air pollution control.

Slotted Ring



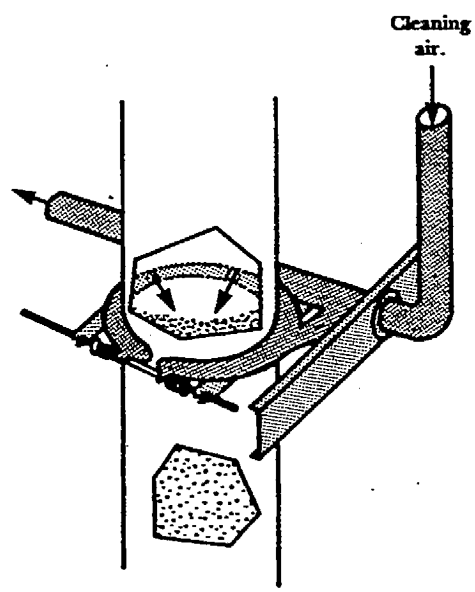


Figure 302.15 Reverse Jet Cleaning Using Blowrings [1]

302.4.5 Bag Cleaning Comparisons

A/C Ratio

One way to compare bag cleaning mechanisms is by examining air-to-cloth ratios. Air-to-cloth (A/C) **ratios** describe how much dirty gas passes through a given surface area of filter in a given time. A high air-to-cloth ratio means a large volume of air passes through the fabric area. A low air-to-cloth ratio means a small volume of air passes through the fabric. The A/C ratios are usually expressed in units of $(ft^3/min)/ft^2$ of cloth $[(cm^3/sec)/cm^2$ of cloth]. The A/C ratio can be used interchangeably with a term called filtration velocity. The units for filtration velocity are ft/min (cm/sec). When using the A/C ratios for comparison purposes one should use the units $(ft^3/min)/ft^2$ or $(cm^3/sec)/cm^2$. Likewise, when using filtration velocities one should use the units ft/min or cm/sec. Air-to-cloth ratios are also called gas-to-cloth ratios. Comparisons of bag cleaning parameters for the three main cleaning methods are shown in table 302.1.

Reverse air cleaning baghouses generally have very low air-to-cloth ratios. For reverse air baghouses, the filtering velocity (filtration velocity) range is usually between 1 and 4 ft/min (0.5 and 2 cm/sec). For shaker baghouses, the filtering velocity ranges between 2 and 6 ft/min (1 and 3 cm/sec). More cloth is generally needed for a given flow rate in a reverse air baghouse than in a shaker baghouse. Hence, reverse air baghouses tend to be larger in size.

Combination Cleaning

Occasionally, baghouse cleaning is accomplished by two methods in **combination**. Many baghouses have been designed with both reverse air and gentle shaking to remove the dust cake from the bag.

Felted Fabrics

Continuous

Pulse jet baghouses are designed with filtering velocities between 5 and 15 ft/min (2.5 to 7.5 cm/sec). Therefore, these units usually use felted fabrics as bag material. **Felted material** holds up very well under the high filtering rate and vigorous pulse jet cleaning. Pulse jet cleaning methods have the advantage of having no moving parts within the compartment. In addition, pulse jet units can clean bags on a **continuous** basis without isolating a compartment from service. The duration of the cleaning time is short (<1.0 second) when compared to the time length between cleaning intervals (approximately 20 minutes to several hours). The major disadvantage of high pressure cleaning methods is that the bags are subjected to more mechanical stress. Fabrics with higher dimensional stability and high tensile strength are required for these units.

Table 302.1 Comparison of Bag Cleaning Parameters [6]

Parameter	Shake Cleaning	Reverse Air Cleaning	Pulse Jet Cleaning
Air-to-cloth ratio	1:1 - 3:1 (cm/sec) 2:1 - 6:1 (ft/min)	0.5:1 - 2:1 (cm/sec) 1:1 - 4:1 (ft/min)	2.5:1 - 7.5:1 (cm/sec) 5:1 - 15:1 (ft/sec)
Frequency	Usually several cycles/second; adjustable.	Cleaned one compartment at a time, sequencing one compartment after another; can be continuous or initiated by a maximum-pressure -drop switch.	Usually a row of bags at a time, sequenced one after another; can sequence such that no adjacent rows clean one after another; initiation of cleaning can be triggered by maximum-pressure-drop switch or may be continuous.
Motion	Simple harmonic or sinusoidal.	Gentle collapse of bag (concave inward) upon deflation; slowly repressurize a compartment after completion of a back-flush.	Shock wave passes down bag; bag distends from cage momentarily.
Peak acceleration	1 to 10 g	--	--
Amplitude	Fraction of an inch to few inches.	--	--
Mode	Off-stream	Off-stream	On-stream
Duration	10 to 100 cycles. 30 sec. to few minutes.	1 to 2 min. including valve opening and closing and dust settling periods; reverse air flow itself normally 10 to 30 sec.	Compressed air (100 psi) pulse duration 0.1 sec; bag row effectively off-line.
Common bag dimensions	5, 8, 12 in. dia. 10,22, 30 ft. length	8, 12 in. dia. 22, 30, 40 ft. length	5 to 6 in. dia.; 8 to 20 ft. length
Bag tension		50 to 75 lb. typical, optimum varies.	--

303 FABRIC TYPES

Bags of all types are available on the market. One may choose from a variety of fiber types, fabric constructions, and fabric coatings. Some of these are described in the following subsections.

303.1 FILTER CONSTRUCTION

Woven and felted materials are used to make bag filters. Woven filters are made of yarn with a definite repeated pattern. Felted filters are composed of randomly placed fibers compressed into a mat and attached to some loosely woven backing material. Woven filters are used with low energy cleaning methods such as shaking and reverse air. Felted fabrics are usually used with higher energy cleaning systems such as pulse jet cleaning.

Woven Filters

Woven filters have open spaces around the fibers. The weave design used will depend on the intended application of the woven fiber. The simplest weave is the plain weave. The yarn is woven over and under to form a checkerboard pattern. This weave is usually the tightest, having the smallest pore openings in the fabric. Consequently, it retains particles very quickly. This weave is not frequently used.

Twill

Other weaves include the twill and sateen (satin). In the twill weave (2/1) yarn is woven over two and under one, but in one direction only.

Sateen

The twill weave does not retain particles as well as the plain weave, but does not tend to blind as fast. It allows good flow rates through the filter and high resistance to abrasion. The satin weave goes one over and four under in both directions. Sateen weave does not retain particles as well as the plain twill weave, but has the best (easiest) cake release when the fabric is cleaned.

Different weaving patterns increase or decrease the open spaces between the fibers. This will affect both fabric strength and permeability. Fabric permeability affects the amount of air passing through the filter at a specified pressure drop. A tight weave, for instance, has low permeability and is better for the capture of small particles at the cost of increased pressure drop.

Sieving

The true filtering surface for the woven filter is not the bag itself, but the dust layer or filter cake. The bag simply provides the surface for capture of larger particles. Particles are collected by impaction or interception and the open areas in the weave are closed. This process is referred to as "**sieving**" (figure 303.1). Some particles escape through the filter until the cake is formed. Once the cake builds up, effective filtering will occur until the bag becomes plugged and cleaning is required. At this point the pressure drop will be exceedingly high and filtering will no longer be cost effective. The effective filtering time will vary from a time of approximately 15 to 20 minutes to as long as a number of hours, depending on the concentration of particulate matter in the gas stream.

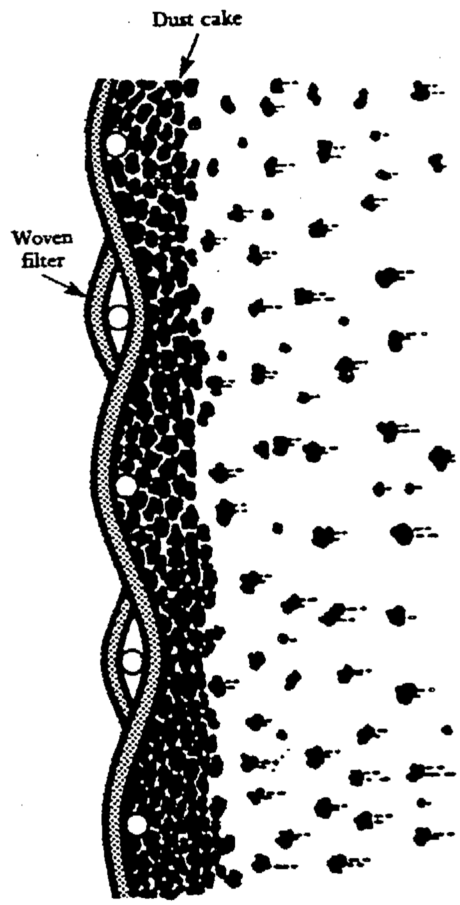


Figure 303.1 Sieving (on a woven filter) [1]

Felted Fibers

Felted filters are made by needle punching fibers onto a woven backing called a scrim. The fibers are randomly placed as opposed to the definite repeated pattern of the woven filter. The felts are attached to the scrim by chemical, heat, resin, and stitch bonding methods.

To collect fine particles, the felted filters depend to a lesser degree on the initial dust deposits than do woven filters. The felted filters are generally 2 to 3 times thicker than woven filters. Each individual randomly oriented fiber acts as a target for particle capture by impaction and interception (see figure 303.2). Small particles can be collected on the outer surface of the filter.

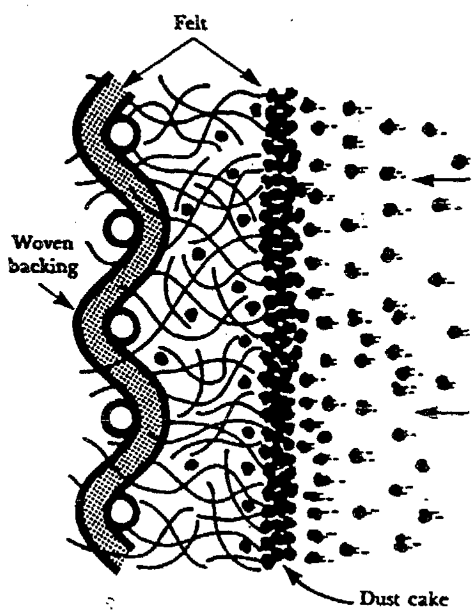


Figure 303.2 Felted fabric filter [1]

303.2 FIBERS

Natural

The fibers used for fabric filters vary depending on the industrial application to be controlled. Some filters are made from natural fibers such as cotton or wool. These fibers are relatively inexpensive but have temperature limitations (<212°C) and only average abrasion resistance. **Cotton** is readily available making it very popular for low temperature simple applications. **Wool** withstands moisture very well and can be made into thick felts easily.

Synthetic

Synthetic fibers such as nylon, Orlon® and polyester have slightly higher temperature limitations and chemical resistances. Synthetic fibers are more expensive than natural fibers. Polypropylene is an expensive synthetic fiber and is used in many industrial applications such as foundries, coal crushers and food industries. Nylon is the most abrasive resistant synthetic fiber making it useful in applications filtering abrasive dusts. Polyester (Dacron®) has good overall qualities to resist acids, alkalines, and abrasion and is relatively inexpensive, making it useful for many industrial processes such as smelters, foundries, and other metal industries. Physical and chemical properties of some fibers are given in tables 303.2 and 303.3.

Nomex® is a registered trademark of fibers made by DuPont. DuPont makes the fibers, not the fabrics or bags. Nomex is widely used because of its relatively high temperature resistance and its resistance to abrasion. It is used for filtering dusts from cement coolers, asphalt batch plants, ferroalloy furnaces, and coal dryers.

Other fibers such as Teflon® and Fiberglas® or glass can be used in very high temperature situations. Teflon has very good resistance to acid attack (except fluorine) and can withstand continuous temperatures up to 445°F (230°C). Fiberglas or glass is often used in baghouses that handle very high temperatures (up to 500°F or 260°C) for continuous operation. Glass fibers are usually lubricated in some fashion so they will slide over one another without breaking or cutting during the cleaning cycle. Graphite is commonly used as a lubricant and will help retain the upper service temperature limits. Glass fibers are susceptible to breakage and require a very gentle cleaning cycle. Both Teflon and glass have been used to remove particulate emissions generated from industrial and utility coal fired boilers.

Another material used to make bags is Gore-tex membrane manufactured by W. G. Gore and Associates, Inc. Gore-tex membrane is laminated with a variety of fibers such as Fiberglas, polyester and Nomex to produce felt and woven filters.

Some reports have indicated very good emission reduction (99.99%), low pressure drops, increased bag life and higher air-to-cloth ratios using this material in metal industries, chemical industries, food industries, and coal fired boilers.

Table 303.1 Recommended Temperature Limits for Various Fabrics [7,8]

Fiber	Generic Name	Maximum gas temperature, °F		Melting Temperature, °F
		Continuous	Short-term	
Cotton	Natural fiber cellulose	180	225	420 decomposes
Wool	Natural fiber protein	200	250	575 chars
Nylon	Nylon polyamide	200	250	520
Dynel	Modacrylic	160	200	440 softens
Polypropylene	Polyolefin	200	250	440
Orlon	Acrylic	275	320	520 softens
Dacron	Polyester	275	325	440
Nomex	Nylon aromatic	400	425	640 decomposes
Teflon	Fluorocarbon	500	530	670 decomposes
Fiberglass	Glass	500	550	1070
Stainless		1000	No data	1700

Table 303.2 Chemical Resistance of Common Commercial Fabrics [7,8,9]

Fiber	Generic Name	Acid resistance	Fluoride resistance	Alkali resistance	Flex and abrasion resistance
Cotton	Natural fiber cellulose	Poor	Poor	Fair to good	Fair to good
Wool	Natural fiber protien	Very good	Poor to fair	Poor to fair	Fair
Nylon	Nylon polymide	Fair	Poor	Very good to excellent	Very good to excellent
Dynel	Modacrylic	Good to very good	Poor	Good to very good	Fair to good
Polypropylene	Polyolefin	Excellent	Poor	Excellent	Very good to excellent
Orion	Acrylic	Good to excellent	Poor to fair	Fair	Fair
Dacron	Polyester		Poor to fair	Fair to good	Very good
Nomex	Nylon aromatic	Fair	Good	Excellent	Very good to excellent
Teflon	Flourocarbon	Excellent	Fair to good	Excellent	Fair
Fiberglass	Glass	Fair to good	Poor	Fair	Poor
Polyethylene	Polyolefin	Very good to excellent	Poor to fair	Very good to excellent	Good
Stainless steel (type 304)		Excellent		Excellent	

303.3 FABRIC TREATMENT

Fabrics are usually pretreated to improve their mechanical and dimensional stability. They can be treated with silicon to give them better cake release properties. Natural fabrics (wool and cotton) are usually preshrunk to eliminate bag shrinkage during operation. Both synthetic and natural fabrics usually undergo processes such as calendering, napping, singeing, glazing, or coating. These processes increase fabric life and improve dimensional stability and ease of bag cleaning. They are described below and in table 303.3.

Calendering is the high pressure pressing of the fabric by rollers to flatten, smooth, or decorate the material. Calendering pushes the surface fibers down on to the body of the filter medium. This is done to increase surface life, dimensional stability and to give a more uniform surface to bag fabric.

Napping is the scraping of the filter surface across metal points or burrs on a revolving cylinder. Napping raises the surface fibers, creating a "fuzz" that provides a large number of sites for particle collection by interception and diffusion. Fabrics used for collecting sticky or oily dusts are occasionally napped to provide good collection and bag cleaning ease.

Singeing is done by passing the filter material over an open flame, removing any straggly surface fibers. This provides a more uniform surface.

Glazing is the high pressure pressing on the fiber at elevated temperatures. The fibers are fused to the body of the filter medium. Glazing improves the mechanical stability of the filter and helps reduce bag shrinkage that occurs from prolonged use.

Coating, or resin treating, involves immersing the filter material in natural or synthetic resin such as polyvinyl chloride, cellulose acetate, or urea-phenol. This is done to lubricate the woven fibers, or to provide high temperature durability or chemical resistance for various fabric materials. For example, glass bags are occasionally coated with Teflon or silicon graphite to prevent abrasion during bag cleaning.

Table 303.3 Summary of Pretreatment Processes [1]

Pretreatment	Method	Result	Reason for use
Calendering	High pressure pressing by rollers	Flattens, smooths, or decorates	Increases surface life. Increases dimensional stability. Provides more uniform fabric surface.
Napping	Scraping across metal points	Raises surface fibers	Provides extra areas for interception and diffusion.
Singeing	Passing over open flame	Removes straggly surface fibers	Provides uniform surface area.
Glazing	High pressure pressing at elevated temperatures	Fibers fused to filter medium	Improves mechanical stability
Coating	Immersing in natural or synthetic resin	Lubricates woven fibers	Provides high temperature durability. Provides chemical resistance for various fabrics.

303.4 BAG FAILURE MECHANISMS

Thermal Durability

Three failure mechanisms can shorten the operating life of a bag. They are related to abrasion, thermal durability and chemical attack. The chief design variable is the upper temperature limit of the fabric. The process exhaust temperature will determine which fabric material should be used for dust collection. Exhaust gas cooling may be feasible, but one must be careful to keep the exhaust gas hot enough to prevent moisture or acid from condensing on the bags.

Abrasion

Another problem frequently encountered in baghouse operation is that of **abrasion**. Bag abrasion can result from bags rubbing against each other, from the type of bag cleaning employed in the baghouse, or where dust enters the bag and contacts the fabric material. For instance, in a shaker baghouse, vigorous shaking may cause premature bag deterioration, particularly at the points where the bags are attached. In pulse jet units, the continual, slight motion of the bags against the supporting cages can also seriously affect bag life. As a result, a 25% per year bag replacement rate is usually encountered. This is the single biggest maintenance problem associated with baghouses.

Chemical Attack

Bag failure can also occur from **chemical attack** to the fabric. Changes in dust composition and exhaust gas temperatures from industrial processes can greatly affect the bag material. If the exhaust gas stream is lowered to its dew point or a new chemical species is created, the design of the baghouse (fabric choice) may be completely inadequate. Proper fabric selection and good process operating practices can help eliminate bag deterioration caused by chemical attack.

304 VARIABLES IN BAGHOUSE DESIGN

Section 302 introduced different types of baghouse designs. This section addresses factors that may determine why a particular design might be chosen.

304.1 PRESSURE DROP

Fan Size

Pressure drop (dp), a very important baghouse design variable, describes the resistance to air flow across the baghouse. Pressure drop is usually expressed in mm of mercury or inches of water. The pressure drop of a system (baghouse) is determined by measuring the difference in total pressure at two points, usually the inlet and the outlet. It can be related to the size of the fan that would be necessary to either push or pull the exhaust gas through the baghouse. A baghouse with a high pressure drop would need a larger **fan** and more energy to move the exhaust gas through the baghouse.

Dust Cake

Many different relationships have been used to estimate the pressure drop across a fabric filter. In a baghouse the total pressure drop is a function of the pressure drop across both the filter and the deposited **dust cake**. Some minor pressure losses due to friction also occur as the gas stream moves through the baghouse.

The simplest equation (equation 304.1) used to predict pressure drop across a filter is derived from Darcy's law governing the flow of fluids through porous materials and is given as:

Darcy's Law

$$dp_f = k_1 v_f \qquad \text{Equation 304.1}$$

where:
dp_f = pressure drop across the clean fabric, in. H_2O (cm H_2O)
k_1 = fabric resistance, in. H_2O/(ft/min) [cm H_2O/(cm/sec)]
v_f = filtration velocity, ft/min (cm/sec)

The term k_1 is the fabric resistance and is a function of exhaust gas viscosity and filter characteristics such as thickness and porosity. Porosity describes the amount of void volume in the filter.

The pressure drop across the deposited dust cake can be estimated by using equation 304.2 (Snyder and Pring, 1955). This formula is also derived from Darcy's law and the simplified form is given as:

$$dp_c = k_2 c_i v_f^2 t \qquad \text{Equation 304.2}$$

where:
dp_c = pressure drop across the cake, in. H_2O [cm H_2O]
k_2 = resistance of the cake, in. $H_2O/((lb/ft^2)(ft/min))$ [cm $H_2O/((g/cm^2)(cm/sec))$]
c_i = dust concentration loading, lb/ft^3 [g/cm^3]
v_f = filtration velocity, ft/min [cm/sec]
t = filtration time, min [sec]

Permeability

The term k_2 is the dust-fabric filter resistance coefficient and is determined experimentally. This coefficient depends on gas viscosity, particle density and dust porosity. The dust porosity is the amount of void volume in the dust cake. The porosity is related to the permeability. **Permeability** for the fabric only is defined in ASTM standard D737-69 as the volume of air which can be passed through one square foot of filter medium with a pressure drop of no more than 0.5 inches of water. The term k_2 is dependent on the size of the particles in the gas stream. If the particles are very small (<2 μm), k_2 is high. If k_2 is high, then the pressure drop will tend to increase and the bags will have to be cleaned more frequently.

The total pressure drop equals the pressure drop across the filter plus the pressure drop across the cake and is given in equation 304.3 as:

$$dp_T = dp_f + dp_c \qquad \text{Equation 304.3}$$
$$dp_T = k_1 v_f + k_2 c_i v_f^2 t$$

Equation 304.3 should be used only as an estimate of pressure drop across shaker and reverse air cleaning baghouses. In the industrial filtration process, complicated particle-fabric interactions are occurring just after the filtration cycle begins. In addition, the filter resistance factor k_1 can take on two values: one value for the clean filter and another after the filter has been cleaned. When the dust cake builds up to a significant thickness the pressure drop will become exceedingly high (>10 in. H_2O or 30.5 cm H_2O). At this time the filter must be cleaned. Some dust will remain on the cloth even after cleaning; therefore, the filter resistance level will be higher than during original conditions. A baghouse is normally operated with a pressure drop across the unit of 3 to 10 in. H_2O or less. Bag cleaning is usually initiated when the pressure drop approaches this point.

304.2 AIR-TO-CLOTH RATIO

The terms "filtration velocity" and "air-to-cloth ratio" can be used interchangeably. The formula used to express filtration velocity is given in equation 304.4 below:

Filtration Velocity

$$v_f = Q/A$$

where:
v_f = **filtration velocity**, ft/min (cm/sec)
Q = volumetric air flow rate, ft^3/min (cm^3/sec)
A_c = area of cloth filter, ft^2 (cm^2)

Air-to-cloth (A/C) ratio is defined as the ratio of gas filtered in cubic feet per minute (cfm) to the area of filtering media in square feet. Typical units used to express the A/C ratio are $(ft^3/min)/ft^2$ or $(cm^3/sec)/cm^2$. These A/C ratios essentially reduce to velocity units.

The A/C ratio (filtration velocity) varies for various baghouse designs, as shown in table 304.1. Shaker and reverse air baghouses generally have small A/C ratios. For shaker units, the ratio is often <3:1 $(cm^3/sec)/cm^2$, while for reverse air units the ratio is often <2.0:1 $(cm^3/sec)/cm^2$. On the other hand, pulse jet units usually operate at A/C ratios between 2.5 and 7.5 $(cm^3/sec)/cm^2$. For a given flow rate, pulse jet units can be smaller in size (fewer bags than shaker and reverse air baghouses).

The A/C ratio (filtering velocity) is a very important factor used in the design and operation of a baghouse. Improper ratios can contribute to inefficient operation of the baghouse. Operating at an A/C ratio that is too high may lead to a number of problems. Very high ratios can cause compaction of dust on the bag, resulting in excessive pressure drops. In addition, breakdown of the dust cake could occur which in turn results in reduced collection efficiency. The major problem of a baghouse using a very low A/C ratio is that the baghouse will be larger in size.

Table 304.1 Air-to-Cloth Ratios for Three Cleaning Mechanisms [1]

Cleaning Mechanism	Air-to-Cloth Ratio	
	$(cm^3/sec)/cm^2$	$(ft^3/min)/ft^2$
Shaker	< 3:1	< 6:1
Reverse Air	< 2:1	< 4:1
Pulse Jet	2.5:1 to 7.5:1	< 15:1

304.3 COLLECTION EFFICIENCY

Extremely small particles can be efficiently collected in a baghouse. Baghouse units designed with collection efficiencies of 99.99% are common. Exhaust air from baghouses can even be recirculated back into the plant for heating purposes, as long as the gas stream is not toxic.

Baghouses are not normally designed with the use of fractional efficiency curves as are some of the other particulate emission control devices. Vendors design and size the units strictly on experience. The baghouse units are designed to meet particulate emission outlet loading and opacity regulations. There is no one formula that can determine the collection efficiency of a specific baghouse. Some theoretical formulas for determining collection efficiency have been suggested, but these formulas contain numerous (3 to 4) experimentally determined coefficients in the equations. Therefore, these efficiency equations give at best only an estimate of baghouse performance.

304.4 GAS TEMPERATURE

Inleakage

The effect of temperature is most important as an indicator of excessive **inleakage** into the gas stream. Even the best-constructed and best-insulated fabric filter will experience some temperature drop, which can be as low as 1 to 2 °F on smaller fabric filters and up to 25 °F on very large fabric filters. Of course, the expected temperature drop will vary, depending on the temperature of the gas stream relative to ambient temperatures. In fact, the temperature drop is normally higher on small collectors than on large ones because the ratio of the outside collector area to gas throughput is generally higher. In any case, some acceptable or maximum difference between inlet and outlet gas temperatures should be set, which when exceeded, would indicate improper operation or a maintenance problem that requires correction.

Dewpoint Temperature

Both maximum and minimum fabric filter operating temperatures must be considered. The exposure of the fabric to temperatures above the maximum exposure temperatures can cause immediate failure due to complete loss of strength and permanent elongation (melting). Minimum temperatures are related to the **dewpoint temperature** of the gas stream. Operation of the fabric filter below this temperature can cause moisture or acid condensation and result in bag blinding or chemical attack of the fabric. Fabric life under these conditions depends on the proper initial choice for application to acid gases such as SO_2, hydrogen chloride (HCl), and hydrogen fluoride (HF).

304.5 CHEMICAL COMPOSITION

Acid Dewpoint

Important factors regarding the chemical composition of the gas stream include moisture content and acid dewpoint. Operating a fabric filter at close to the **acid dewpoint** presents a substantial risk of corrosion, especially in localized spots close to hatches, in dead air pockets, in hoppers, or in adjacent heat sinks (such as external supports). If the operating temperature drops below the water dewpoint, either during startup or under normal operation, blinding of the bags can occur. Trace components such as fluorine also can attack certain fabrics. For example, fiberglass bags exposed to 200 ppm of HF at 500 °F may last 2 years, while 1200 ppm of HF at 500 °F may result in a bag life of only 2 months.

304.6 MASS LOADING AND SIZE DISTRIBUTION

Mass loading and size distribution must be considered during the design of a fabric filter and also during operation; however, within certain limitations (±10 - 20 percent of design values), changes in these parameters do not seriously affect fabric filter efficiency. Nevertheless, an increase in mass loading may require more frequent cleaning of the bags as a result of faster filter cake buildup. When bag failures occur due to the presence of **large abrasive particles**, the use of a precleaner or a gas distribution device (i.e., an inlet diffuser) at the fabric filter inlet may be required. For some sources, such as spreader stoker boilers, installation of a mechanical collector ahead of the fabric filter may be necessary to protect the bags from the large number of >10-micrometer particles and from glowing embers.

Large Particles

Mass loading at the inlet and outlet of the fabric filter is usually measured by standard reference methods. The difference between the amount of material in the outlet gas stream and the inlet gas stream provides the basis for removal efficiency calculations. The use of the reference sampling methods, however, can be difficult on processes that generate very high mass loadings at the fabric filter inlet. When outlet mass loadings are very low, long sampling times maybe required to collect enough material for accurate weighing. Also, simultaneous sampling of inlet loadings during the entire test period may not always be possible if the loadings are so high that the sampling train becomes overloaded. In some instances, a series of probes inserted for 1 to 15 minutes to take **"grab" samples** of the inlet concentration may be all that is technically feasible. Although this may not provide as accurate a value for inlet mass loading as would an "integrated" sample taken concurrently with the outlet emissions test, it will give a reasonable value to work with.

Grab Samples

304.6.1 Particle Sizing Techniques

Measurements of particle size distribution in industrial flue gas streams are made for several reasons. The aerosol must be characterized as completely as possible in order to assess the potential for adverse health or environmental effects; emission measurements can be useful as a process monitor; and the aerosol particle size distribution must be known in order to completely quantify the behavior of a control device. Also, particle size measurements on uncontrolled sources are useful in baghouse design.

300 THEORY AND DESIGN

Any detailed experimental program designed to evaluate a baghouse must include measurements on the particle size distributions at the inlet and outlet. These size distributions can then be used to calculate the baghouse collection efficiency versus particle size, or "fractional efficiency curve."

Opacity

Fine particles are more difficult to collect than large particles. Unfortunately, fine particles contribute more to visible light scattering and **opacity** and present a greater health hazard than do the larger particles. Although most of the mass emitted from a particular pollution source may consist of large particles, in general the largest number of particles is in the fine particle range. Thus, high mass collection efficiency does not always imply high number collection efficiency, nor does it ensure that a particular opacity standard will be met.

An ideal particle size measurement device would be located *in situ* and give a real-time readout of particle size distributions and particle number concentration over the size range from 0.01 micron to 10 microns diameter. At the present time, however, particle size distribution measurements are made using several instruments which operate over limited size ranges and do not yield instantaneous data.

In-Stack Sampling

Particle sizing methods may involve instruments which are operated **in-stack**, or out of stack where samples are taken using probes. For in-stack sampling, the sample aerosol flow rate is usually adjusted to maintain near isokinetic sampling conditions in order to avoid concentration errors which result from under or oversampling large particles (greater than 3 microns diameter) which have too high an inertia to follow the gas streamlines in the vicinity of the sampling nozzle. Since many particulate sizing devices have size fractionation points that are flow rate dependent, the necessity for isokinetic sampling in the case of large particles can result in undesirable compromises in obtaining data - either in the number of points sampled or in the validity or precision of the data for larger particles.

Stratification

In general, particulate concentrations within a duct or flue are **stratified** to some degree with strong gradients often found for larger particles and in some cases for small particles. Such concentration gradients, which can be due to inertial effects and gravitational settling, imply that multipoint (traverse) sampling must be used.

Even the careful use of multipoint traverse techniques will not guarantee that representative data are obtained. The location of the sampling points during process changes or variations in baghouse operation can lead to significant scatter in the data. Similar effects will occur in other instances as a result of process variations and stratification due to settling and cyclonic flows.

Choices of particulate measurement devices or methods for individual applications are dependent on the availability of suitable techniques which permit the required temporal and/or spatial resolution or integration. In many instances the properties of the particulate are subject to large changes in not only size distribution and concentration, but also in chemical composition (for example, emissions from the open hearth steel making process). Different methods or sampling devices are generally required to obtain data for long term process averages as opposed to the isolation of certain portions of the process in order to determine the cause of a particular type of emission.

Interferences

Interferences exist which can affect most sampling methods. Two commonly occurring problems are the condensation of vapor phase components from the gas stream and reactions of gas, liquid, or solid phase materials with various portions of the sampling systems. An example of the latter is the formation of sulfates in appreciable (several milligram) quantities on several of the commonly used glass fiber filter media by reactions involving SO_x and trace constituents of the filter media. Sulfuric acid condensation in cascade impactors and in the probes used for extractive sampling is an example of the former.

If extractive sampling is used and the sample is conveyed through lengthy probes and transport lines, as is the case with several particulate sizing methods, special attention must be given toward recognition, minimization, and compensation for losses by various mechanisms in the transport lines. The degree of such losses can be quite large for certain particle sizes.

304.6.2 Various Particle Sizing Devices

If one were able to design an **ideal particle measuring device**, the device would have the following features:

Ideal Device

1. It would be able to measure the exact size of each particle.
2. It would report data instantaneously without averaging data over some specified time interval.
3. It would determine the complete composition of each particle including shape, density, and chemical nature.

The production of such an instrument is an extremely difficult task. At this time there are devices which incorporate only one or two of these ideal functions. The following sections deal with a few of the available devices, listing advantages and disadvantages of each. Table 304.2 presents the size range capabilities of various measuring devices.

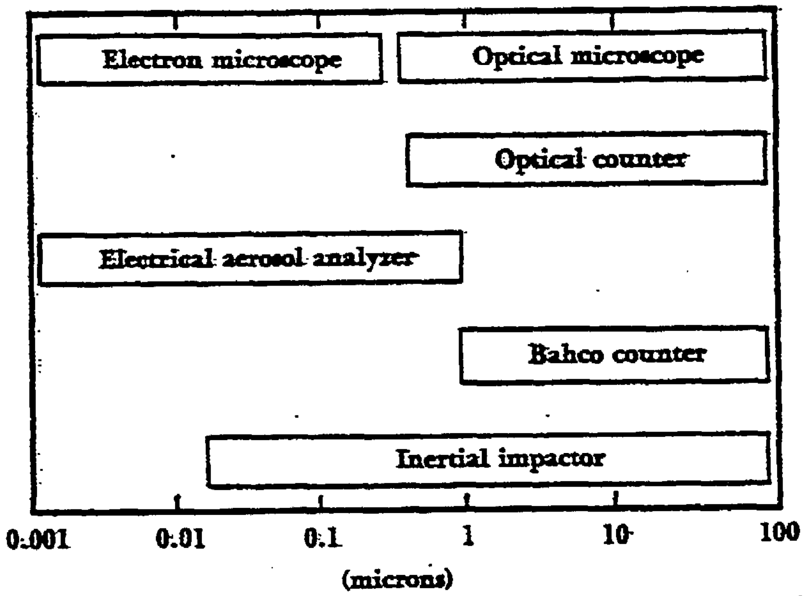


Table 304.2 Size Range Capabilities of Measuring Devices [10]

Microscopy

The light microscope is used commonly in particle sizing analysis. With the microscope, one can measure the geometric size of each particle. The determination of particle size is carried out by measuring the size of a number of particles. Particles are sized as they traverse past the eyepiece micrometer. Each particle, presented in a fixed area of the eyepiece, is sized and tallied into a number of size classes. The number of particles sized may range from 100 to several thousand depending on the accuracy desired. This method can be time consuming and extremely tedious.

The particles may be collected by deposition on a glass slide or filter by using a Method 5 sampling train. The glass slide or filter would subsequently be analyzed by a microscope in a lab. The analysis of size distribution of particles collected in the field and transported to the lab must be viewed with great caution. It is difficult to collect a representative sample in the first place, and it is almost impossible to maintain the original size distribution under laboratory conditions. For example, laboratory measurements cannot determine whether some of the particles existed in the process stream as agglomerates of smaller particles. In spite of the limitations of the microscopic method, this method is useful in the determination of some properties of interest.

Generally speaking, the chemical composition of the particle cannot be obtained by using an optical microscope. However, a subsequent chemical analysis can be performed on the sample. The electron microscope, on the other hand, can give a detailed chemical analysis of the particle. The electron microscope is used in conjunction with an x-ray diffraction attachment to determine the molecular weight of the particle. Particles with molecular weights greater than carbon can be determined by the amount of radiation diffracted by each particle analyzed.

Electron Microscope

The optical microscope can measure particles from about 0.5 micron to about 100 microns in diameter. **Electron microscopes** can measure particles with diameters as small as 0.001 micron. This could be useful for examining extremely minute particles.

Optical Counters

Optical particle counters have not been widely used for particle sizing because they cannot be directly applied to the stack exhaust gas stream. The sample must be extracted, cooled and diluted before entering the counter. This procedure must be done with extreme care to avoid introducing serious errors in the sample. The major advantage of the counter is its capability of observing emission (particle) fluctuations on an instantaneous level. One can size particles as small as 0.3 micron with the optical counter.

Optical particle counters work on the principle of light scattering. Each particle in a continuously flowing sample stream is passed through a small illuminated viewing chamber. Light scattered by the particles is sensed by the photodetector during the time the particle is in the viewing chamber (see figure 304.1). The intensity of the scattered light is a function of particle size, shape, and index of refraction. Optical counters will give reliable particle size information only if one particle is in the viewing chamber at a time. The simultaneous presence of more than one particle can be interpreted by the photodetector as a larger sized particle. This error can be avoided by maintaining sample dilution at less than 300 particles per cubic meter.

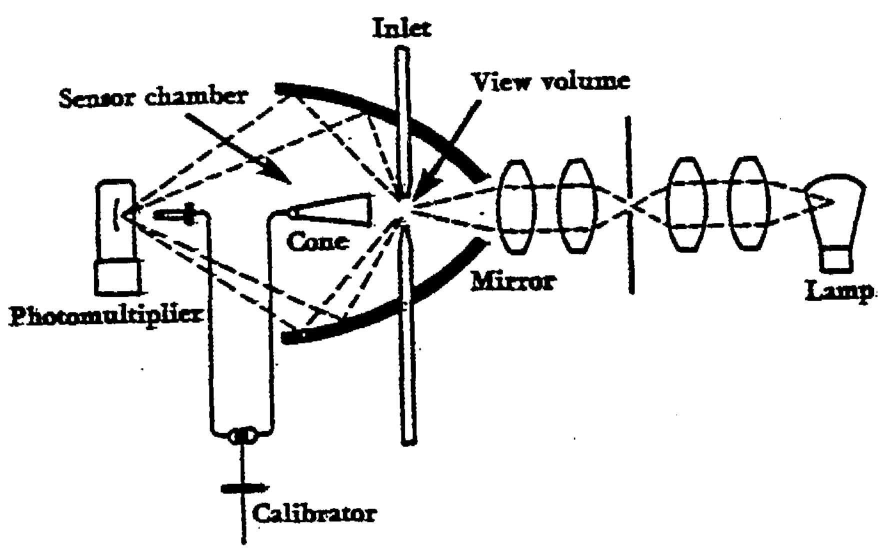


Figure 304.1 Operating Principle for an Optical Particle Counter [10]

A disadvantage of the optical counter is the dependence of calibration of the instrument upon the index of refraction and shape of the particle. Errors in counting can also occur from the presence of high concentrations of very small particles which are sensitive to the light wavelength used.

Electrical Aerosol Analyzer

The electrical aerosol analyzer (EAA) is an aerosol size distribution measuring device that was commercially developed at the University of Minnesota. The EAA uses an electric field, which is set at an intensity dependent upon the size and mass of the particle, to measure the mobility of a charged aerosol. The analyzer operates by first placing a unipolar **charge on the aerosol** being measured, and measuring the resulting mobility distribution of the charged particles by means of a mobility analyzer.

Charged Aerosol

Charged particles enter through a narrow passage and experience a radial force toward the central cylinder due to the applied field. By moving the sampling groove axially, or by varying the applied field, the mobility of the charged particles can be measured. One type of EAA is shown in figure 304.2.

The EAA has been used for source analysis by pulling a sample from the stack into the chamber and introducing the gas stream into the analyzer. The instrument requires that enough particles pass through the chamber so that a charge can be detected. The concentration range for most efficient operation of the EAA is from 1 to 1000 microgram per cubic meter. Since stack gas concentrations usually exceed 1000 micrograms per m^3, sample dilution with clean air is required. No information on the chemical composition of the particles is possible since the particles are not collected. The major advantage of the EAA is that the instrument can measure particles from 0.003 to 1.0 micron in diameter.

Bahco Microparticle Classifier

The Bahco (figure 304.3) is a versatile particle classifier used for measuring powders, dust, and other finely divided solid materials. The Bahco's working range is approximately 1 to 60 microns. Developed in the 1950's, the Bahco has lost some of its initial appeal to more recently developed techniques.

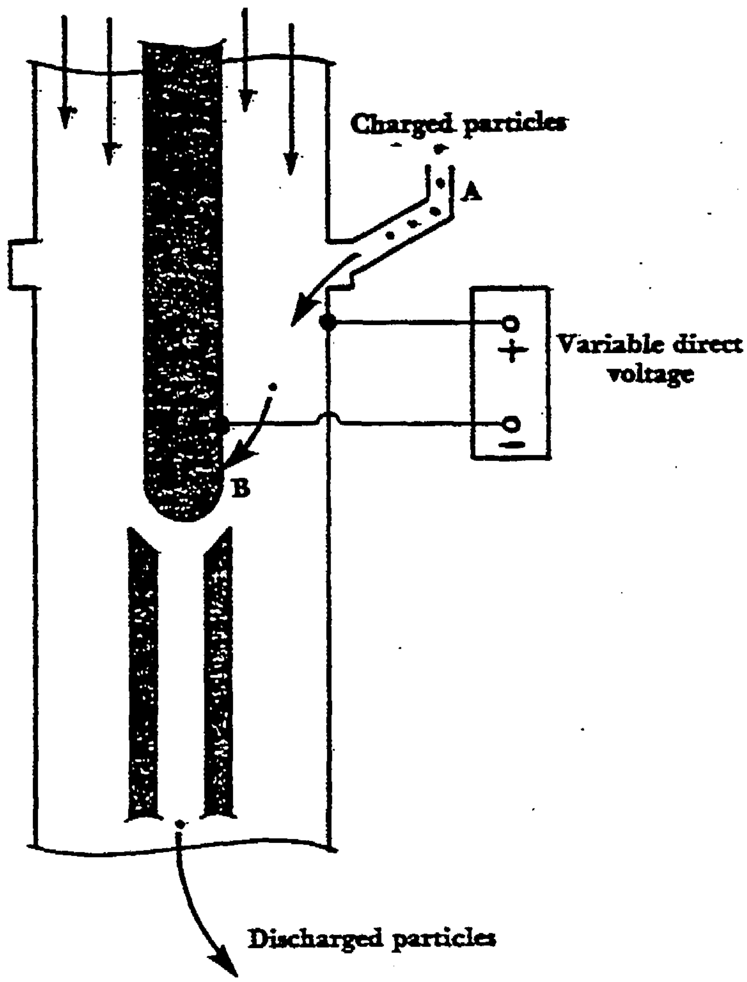


Figure 304.2 Coaxial Cylinder Mobility Analyzer [10]

The Bahco uses a combination of elutriation and centrifugation to separate particles in an air stream. Particles can be collected onto a filter by using a Method 5 sampling train. The collected particles are subsequently analyzed in the lab.

A weighed sample, usually 5 grams, is introduced into a spiral-shaped air current to separate the particle fractions. The larger particles overcome the viscous forces of the fluid and migrate to the wall of the chamber, while the smaller particles remain suspended. After the two size fractions are separated, one of them is reintroduced into the device and is fractionated further. A different spin speed is used to give a slightly different centrifugal force. This is repeated as many times as desired to give an adequate size distribution. The measurements are grouped into discrete size ranges (i.e. 40 - 60 microns, 20 - 40 microns, etc.).

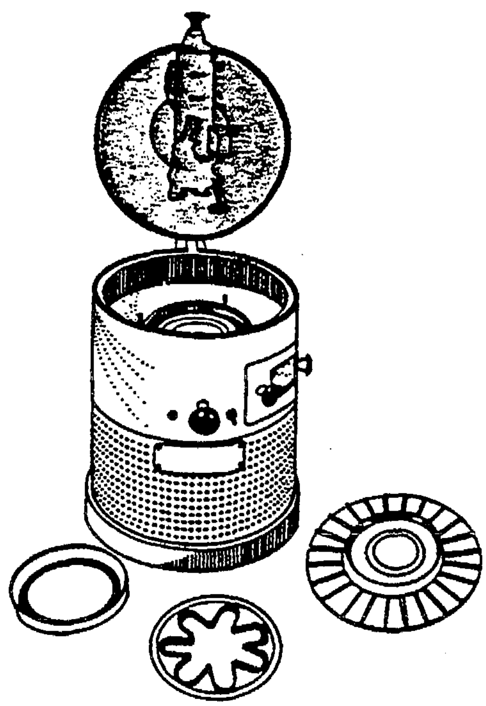


Figure 304.3 Bahco Sampler [10]

The Bahco provides information on the aerodynamic size of the particles. This data can be translated into settling velocity information useful in the design of emission control devices. Several hours are required to complete the fractionation analysis. Once the particles have been fractionated into the discrete ranges, a chemical analysis can be done on the collected particles.

Some of the major drawbacks of the Bahco are that:

1. The working range is limited to between 1 and 60 microns;
2. Care must be exercised when measuring certain types of particles, especially those which are friable or hygroscopic;
3. The sample may not be representative due to particle agglomeration, either in the stack or during the transfer of the collected sample in the lab;
4. The length of time required for analysis is several hours or more;
5. The size grading regimes are not as sharp as with newer devices.

Impactors

Inertial impactors are commonly used to determine the particle size distribution of exhaust streams from industrial sources. Inertial impactors measure the aerodynamic diameter of the particles. The inertial impactor can be directly attached to a Method 5 sampling train and can be easily inserted into the stack of an industrial source.

The mechanism by which an impactor operates is illustrated in figure 304.4. The impactor is constructed using a succession of stages, each containing orifice openings with an impaction slide or collection plate behind the openings. In each stage, the gas stream passes through the orifice opening and forms a jet which is directed towards the impaction plate. The larger particles will impact on the plate if their momentum is large enough to overcome the drag of the air stream as it moves around the plate. Since each successive orifice opening is smaller than those on the preceeding stage, the velocity of the air stream, and therefore that of the dispersed particles, is increased as the gas stream advances through the impactor. Consequently, smaller particles eventually acquire enough momentum to break away from the gas streamlines to impact on a plate. A complete particle size classification of the gas stream is therefore achieved.

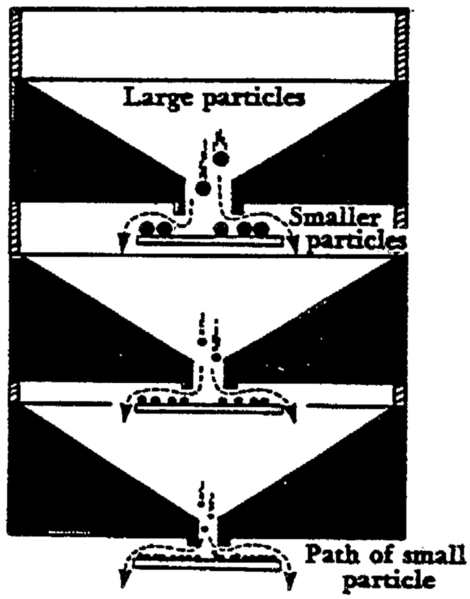


Figure 304.4 Operation of an Inertial Impactor [10]

Typical impactors consist of a series of stacked stages and collection surfaces. Depending on the calibration requirements, each stage contains from one to as many as 400 precisely drilled jet orifices, identical in diameter in each succeeding stage (figure 304.5). Adhesive, electrostatic, and van der Waals forces hold the particles to each other and to the collection surfaces. Moreover, the particles are not blown off the collecting plate by the jets of air because these jets follow laminar flow paths so that no turbulent areas exist. This results in complete dead air spaces over and around the samples.

Particles are collected on preweighed individual stages, usually filters made of glass fiber or thin metal foil. Once the sample is complete, the collection filters are weighed again, yielding particle size distribution data for the various collection stages. Occasionally there are some dusts that are very difficult to collect, and require grease on the collection filter for adequate particle capture. Once the particles have been fractionated into discrete ranges, a chemical analysis can be performed on the collected particles.

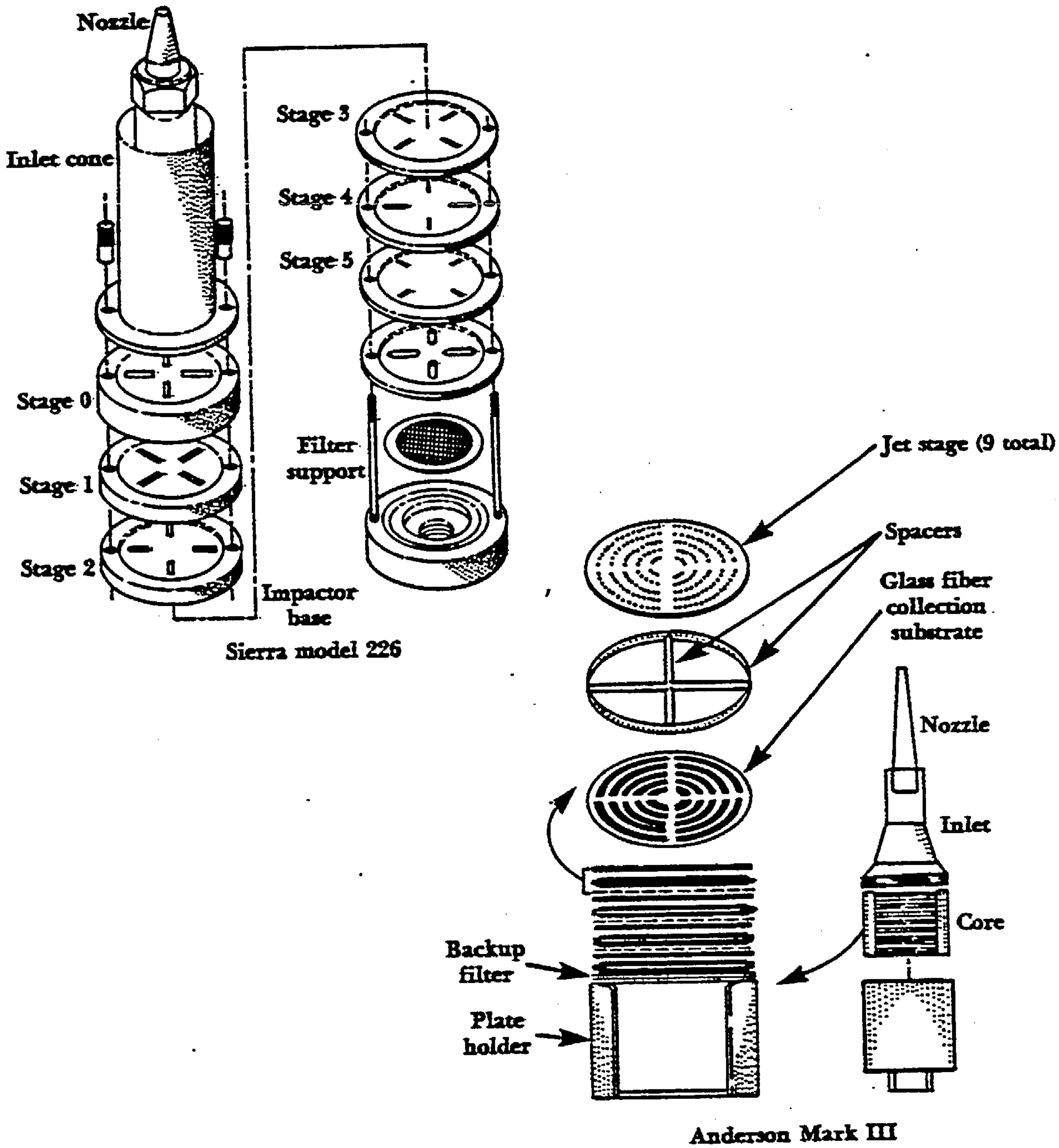


Figure 304.5 Schematics of Two Commercial Cascade Impactors [10]

The effective range for measuring the aerodynamic diameter is generally between 0.3 and 20 microns. Some vendors have claimed size fractionation as small as 0.02 micron with the use of 20 or more stages. Impactors are one of the most useful devices for determining particle size. This is because of the impactor's compact arrangement, mechanical stability, and its ability to draw a sample directly from a stack. In addition, the impactor measures the aerodynamic diameter of particles, which describes the movement of the particles in a gas stream. Particle movement information is extremely useful in designing air pollution control equipment.

305 AUXILIARY EQUIPMENT

Complete fabric filtration systems typically consist of equipment in addition to the baghouse with bags and bag cleaning systems. These have been described in previous sections of this manual. This section treats auxiliary equipment — components used to establish and control air flow through the baghouse, and also dust handling equipment to dispose of the dust filtered from the gas stream.

305.1 GAS CONDITIONING

Occasionally it is necessary to cool the process gas stream before the gas goes to the baghouse. Since there is an upper temperature limit on the fabrics used for bags, gas cooling is sometimes necessary to preserve bag life. This can be accomplished by a number of cooling methods.

Dilution

Dilution of the exhaust gas stream by air is the easiest and cheapest method, especially at very high temperatures. However, air dilution requires the use of a larger baghouse to handle the increased volume of air. Other problems can arise due to the difficulty of controlling the intake of ambient moisture and other contaminants from the dilution air intake.

Radiation Cooling

Radiation cooling can also be used to lower the process exhaust gas temperature. Radiation cooling involves the use of long uninsulated ducts that allow the gas stream to cool as heat radiates from the duct walls. Ducts can be designed in "U" shapes to allow more duct surface area to be exposed for radiation cooling. Radiation cooling would not normally be very effective to cool gas temperatures below 572 °F or 300 °C. This would require substantial surface area, lengthy duct runs, and increased fan horsepower. Precise temperature control is difficult to maintain and there is a possibility of the ducts becoming plugged due to particle sedimentation.

Evaporative Cooling

Evaporative cooling is also used to reduce exhaust gas stream temperature. Evaporative cooling is accomplished by injecting fine water droplets into the gas stream. The water droplets absorb heat from the gas stream as they evaporate. Spray nozzles are located in a quench chamber or somewhere in the duct preceding the baghouse. Evaporative cooling gives a great amount of controlled cooling at a relatively low installation cost. Temperature control can be flexible and accurate. However, this cooling method may increase the exhaust volume to the baghouse. The biggest problem with evaporative cooling is keeping the gas temperature above the dew point of the gas (SO_2, NO_2, HCl, etc.). Otherwise, gases may condense on the bags causing rapid bag deterioration. In addition, all moisture injected into the gas must be evaporated to prevent corrosion of metal parts and blinding or plugging of the bags.

305.2 GAS INLET EQUIPMENT

If an adequately designed baffle plate is not used to remove large, abrasive particles, abrasion can occur, particularly on the surface of the bag near the cuff. More abrasion problems occur near the bottom of the bags, directly above the thimbles. The installation of thimble extensions, a blast plate, or a precleaner can reduce the abrasive damage and extend bag life.

Baffle Plate

Baffle plates or diffusers are used to cause large particles to deposit in the hopper before they contact the bags. The orientation of the plates is critical, however, because deflection of incoming gas into the hopper can resuspend collected dust and increase dust loading through the tube sheet. Less resuspension will occur if the hoppers are operated with continuous dust removal and the dust remains below the gas inlet. Screw conveyor discharge also should be on the opposite side from the gas inlet to minimize reentrainment. Because baffle plates suffer continuous erosion, they must be replaced periodically. An increase in bag ruptures near the cuff area may indicate the need to replace a baffle plate or to correct other problems with the tube sheet thimble.

Thimble

A good thimble arrangement will also reduce abrasion at the bottom of bags in reverse-air and shaker-type collectors. The thimbles should be at least one bag diameter long to prevent abrasion caused by particulate "turning the corner" at the cell plate and being thrown to the outside by inertial force. The **thimbles** act as flow straighteners and protect the bottom of the bag from excessive abrasion. The rounded edge on the top of the thimble reduces cutting of the fabric even if tension is not optimum. For units in which the base snaps into the tube sheet, a thimble can be added that extends downward to provide the same type of abrasion protection as that shown in the illustration.

Bypass

A **bypass** may be advisable, especially when process startup or upset conditions could generate sticky particulate or result in gas temperatures below the acid vapor or water dewpoints. These could also be used in conjunction with a spark sensor to reduce risk of fire.

Dampers

Inlet and outlet **dampers** (figure 305.1) should be provided in compartmentalized systems to allow on-line maintenance. The dampers must be designed to provide positive sealing so as to protect maintenance personnel from toxic gases.

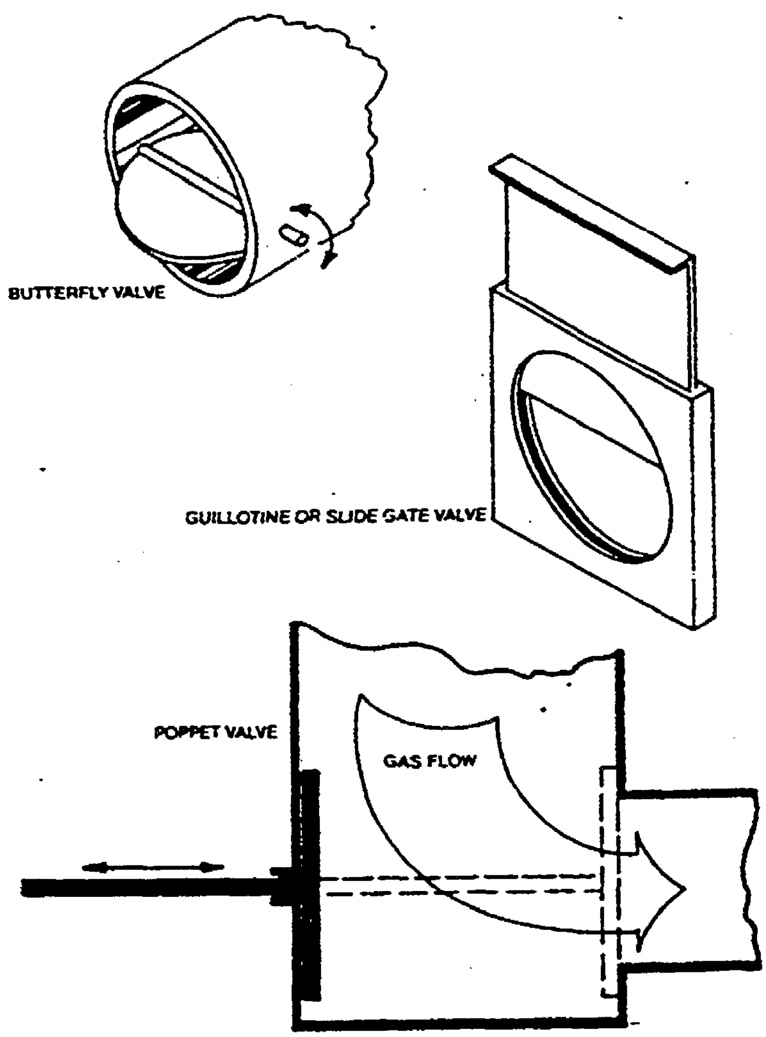


Figure 305.1 Typical Damper Valves Used in Baghouse Systems [11]

305.3 HOUSING

Baghouses are constructed as single or compartmental units. The single unit is generally used on small processes that are not in continuous operation such as grinding and paint spraying processes. Compartmental units consist of more than one baghouse compartment and are used in continuous operating processes with large exhaust volumes such as electric melt steel furnaces and industrial boilers. In both cases, the bags are housed in a shell made of a rigid metal material. Occasionally it is necessary to include **insulation** with the shell when treating high temperature flue gas. This is done to prevent moisture or acid mist from condensing in the unit, causing corrosion and rapid deterioration of the baghouse.

Insulation

305.4 BAG SUPPORT SYSTEM

The bags and the associated fabric filter components (such as the tube sheet, clamps, thimbles, and bag cages) must be compatible for optimum bag life and control efficiency.

In shaker and reverse-air fabric filters, the bag can be attached to the tube sheet by a thimble and clamp ring design or by a snap-ring design (see figures 305.2 and 305.3). Dust enters the fabric filter at the hopper in a horizontal direction and must make a vertical turn to enter the tube sheet thimbles. Because heavy particles with higher inertia do not follow the flow, they do not enter the opening parallel to the thimble walls. The particles impact on the walls of the thimble and, if the thimble is short, on the fabric above the thimble. The action of the particles striking at an angle to the fabric surface increases abrasion. Roughly 90 percent of bag failures occur near the thimble. The use of double-layered fabric (cuffs) or longer thimbles reduces the failure rate.

In the snap-ring system, no thimble is used, and in some cases, a cuff is not used. This exposes the bag to rapid abrasion a few inches above the snap ring. Add-on tube sheet thimbles maybe used to reduce this abrasion.

In the no-thimble design, improper installation of the snap ring can result in dust penetration between the tube sheet and the bag cuff. If the ring seating is questionable, the bag should be removed and reinstalled. If an adequate fit cannot be achieved, the bag should be discarded.

Proper bag tension is important in ensuring adequate bag life and minimum particulate emissions. The bag should be tight enough to provide optimum utilization of cleaning energy. It may be necessary to check bag tension soon after startup. For uniform cleaning efficiency, the tension must be uniform in all the bags. Proper tension also reduces bag failures at the cuff, lessens wear on thimbles, and improves cleaning efficiency. It should also be noted that tension varies throughout the cleaning cycle and with bag age.

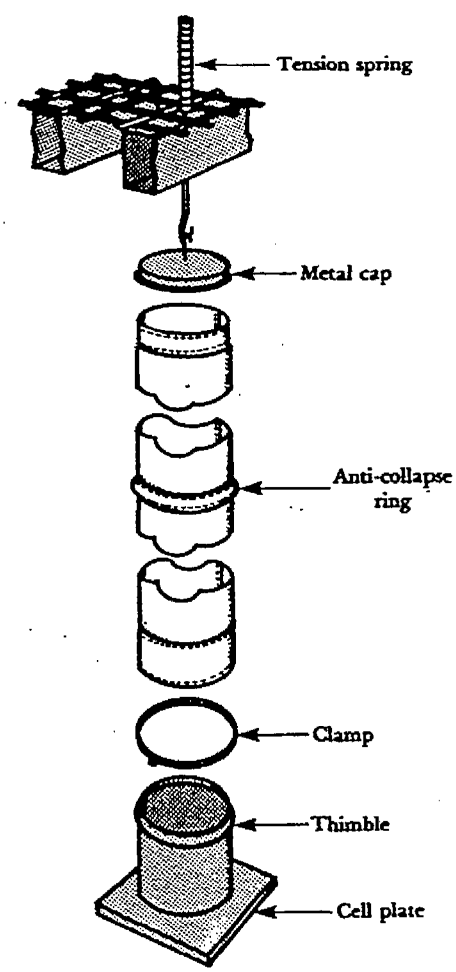


Figure 305.2 Bag Construction (for a Reverse Air Baghouse)[1]

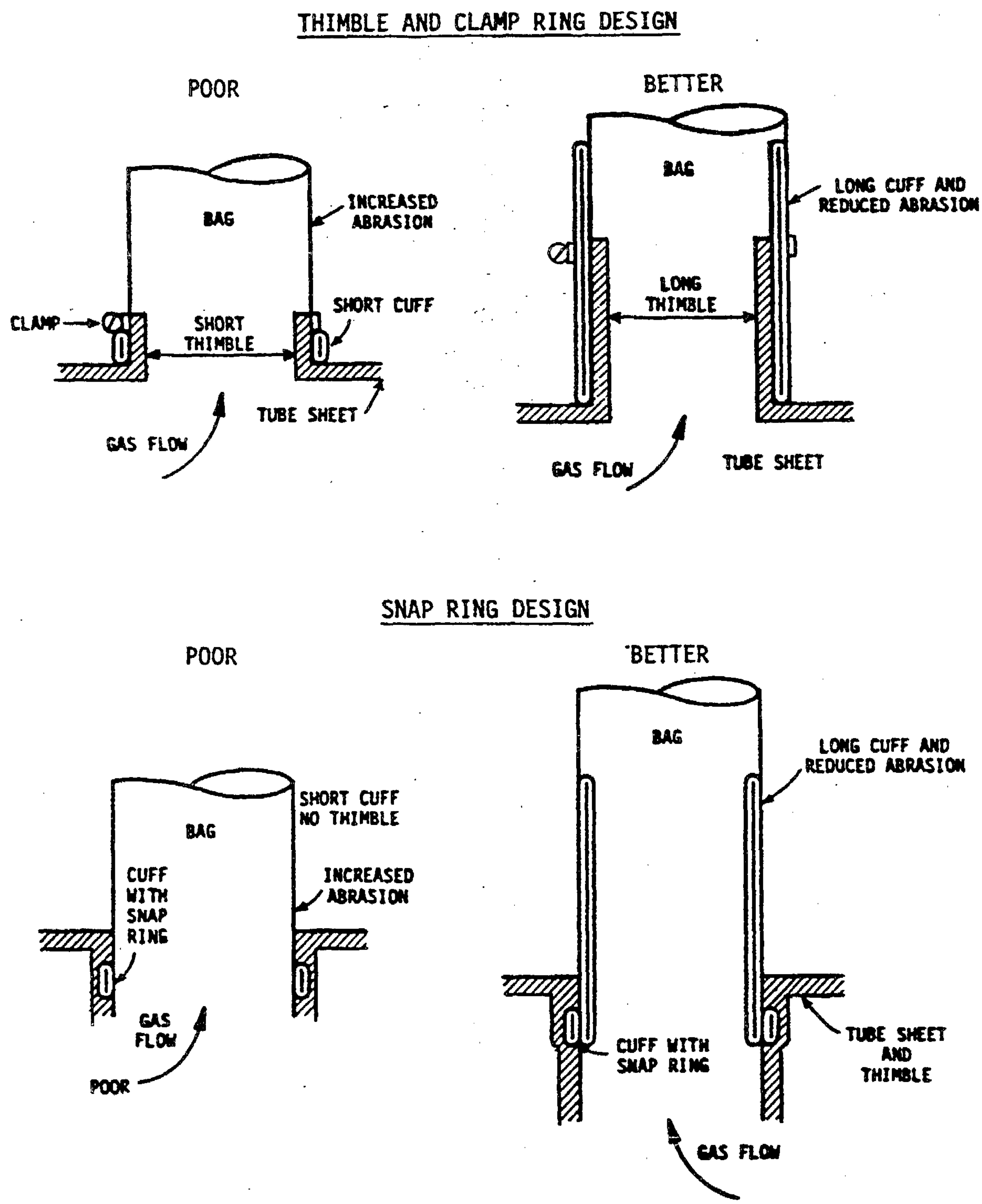


Figure 305.3 Methods of Bag Attachment in Shaker and Reverse Air Fabric Filters[12]

305.5 HOPPERS AND DUST HANDLING SYSTEM

As solids are cleaned from the filtering fabric, they fall into a collection hopper for ultimate removal. The "fluid" properties of the collected solids are important to the design and operation of these systems, and they may be markedly different from the properties of the material from which they originated. Fine dusts, for example, tend to pack more readily than coarser materials; moreover, condensation formed in the filter device may cause solid material to agglomerate. Both of these factors can make solids disposal difficult.

Various design features can help to prevent the clogging of solid collection hoppers. The hopper should be designed with a steep valley angle; angles of 55 to 70 degrees are recommended. Hoppers should also include large discharge openings, well finished (smooth) surfaces, and minimal ledges or other obstructions on sidewalls. A hopper is shown in figure 305.4. The top of the hopper sidewall should drop vertically and the slope to the discharge point should begin at least one bag diameter below the bottom of the bags to allow proper dust discharge. At least one foot of clearance should be provided between hopper walls and any internal partitions to allow easy discharge.

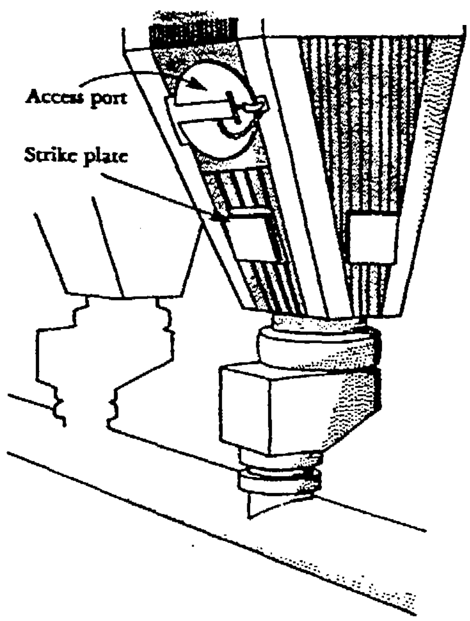


Figure 305.4 Hopper[1]

Heaters and insulation can be installed in hoppers to prevent **condensation** and caking of collected material. Hopper stones supplied with hot dry air can also be used to fluidize material in the hopper and keep it free-flowing.

Condensation

Solids are generally removed from the hopper by means of a discharge valve, which removes ash from the hopper while preserving the pressure differential between the dust conveyance system and the fabric filter system.

Insulating the fabric filter helps to maintain the temperature of the gas while it is being cleaned. Temperatures above the acid dew point minimize **corrosion** of hanger components, doors, and walls. Internal shell components can also be lined with appropriate corrosion-resistant materials if necessary. Structural steel may be placed on the internal portion of the shell. The insulation may then be applied evenly across the shell to reduce "cold spots" which promote corrosion of the shell.

Corrosion

Automatic continuous discharge devices are installed on baghouses that are used in continuous operation. Some devices include trickle valves, rotary airlock valves, screw conveyors or rotary conveyors. As dust collects in the hopper, the weight of the dust pushes down on the counterweight of the top flap and dust discharges downward. The top flap then closes, the bottom flap opens, and the material falls out. This type of valve is available in gravity-operated and motorized versions.

Rotary **airlock valves** are used in medium or large sized baghouses. The valve is designed with a paddle wheel which is shaft-mounted and driven by a motor. The rotary valve is similar to a revolving door: the paddles or blades form an airtight seal with the housing; and the motor slowly moves the blades to allow the dust to discharge from the hopper.

Airlock Valves

Other automatic dust discharge devices include **screw and pneumatic conveyors**. Screw conveyors employ a revolving screw feeder located at the bottom of the hopper to remove the dust from the bin. Pneumatic conveyors use compressed air to blow (remove) dust from the hopper.

Screw and Pneumatic Conveyors

306 INSTRUMENTATION

The following instrumentation contributes to the reliable operation of a fabric filter.

1. Flow meters.

2. Thermocouples or other temperature-measuring instruments at the device outlet.

3. Inlet/outlet differential static pressure gauges.

4. A double-pass transmissometer (opacity meter).

5. Hopper level indicators.

6. Compressed-air pressure gauge.

The instrument readouts should be mounted on a master control panel as close as possible to other process monitoring displays. The readings of thermocouples, pressure differential gages, and transmissometers can all be electronically recorded for permanent records.

306.1 FLOW METERS

A pitot tube traverse is normally used to measure total gas volume, and the method is usually a combination of EPA Reference Methods 1 and 2. In this method, the duct on the cross section of the stack is divided into a number of equal areas, and each area is sampled to arrive at an average velocity through the duct. When the average velocity and the duct or stack cross-sectional area is known, the average gas volume can be determined. Because most facilities do not routinely measure gas volume, other indirect indicators may be used to estimate the volume. These include fan operating parameters, production rate, and a combination of other gas condition parameters.

306.2 TEMPERATURE MONITORS

Monitoring the temperature of the gas stream can provide information about the performance of a fabric filter and clues for diagnosing both fabric filter performance and process operating conditions. The major concern in temperature measurement is to avoid sampling at a stratified point where the measured temperature is not representative of the bulk gas flow. Thermocouples with digital, analog, or strip-chart display are typically used.

Alarm

Temperature monitoring is also important for minimizing bag damage due to temperature exposure above the fabric's design limits. Even a temporary excursion above fabric temperature limits can weaken bags. An **alarm** tied to a regularly maintained thermocouple probe may prevent bag failure due to temperature excursion. This alarm can be used in conjunction with an automatic method of protection, such as dilution air or bypass. The effects of repeated temperature excursions are cumulative, and temperature charts can be used to determine the potential for short-term failure due to temperature excursions. It should be noted that the use of only one probe does not represent the temperature in each section of the fabric filter, but rather only the average.

306.3 PRESSURE MONITORS

Typically, pressure drop in a baghouse is measured by differential pressure gauges. In lieu of differential pressure gauges, it is sometimes simpler to install static pressure taps, where appropriate, and to use a portable meter to obtain readings. This approach reduces problems of meter moisture damage, meter corrosion, and plugging of lines. If permanent differential static pressure gauges are used, the static pressure lines should be as short as possible and free of 90-degree elbows to minimize plugging. Copper tubing in a noncorrosive environment has been found to be less susceptible to deterioration than the polypropylene lines commonly used. However, PVC is even better because of its resistance to corrosive conditions.

306.4 OPACITY METERS

Transmissometer

The double-pass **transmissometer** (opacity meter) may not provide an accurate measurement of effluent opacity; however, it is useful in identifying problems. A significant leak is detected in a specific compartment by a drop in the opacity when that compartment is off-line for maintenance in shaker and reverse-air fabric filters. A pinhole leak can be identified in pulse-jet filters by an increase in opacity a few seconds after the row of bags that contains the pinhole leak is cleaned.

Section 403.4 of this manual gives more details on opacity meters and how they should be inspected.

306.5 HOPPER LEVEL INDICATORS

Alarm

Hopper level indicators could more accurately be called hopper level alarms because they do not actually measure dust levels inside the hopper; instead, when the dust level becomes higher than the level detector, an **alarm** sounds to indicate that corrective action is necessary. The level detector should be placed high enough that "normal" dust levels will not continuously set off the alarm, but low enough to allow adequate response time to clear the hopper before the dust reaches the tube sheet and causes blocking of the inlet to the bags. Not all fabric filters use or need hopper level indicators.

Two types of level indicators are most commonly used (although others are available). The older of the two, a capacitance probe, is inserted into the hopper. As dust builds up around the probe, a change in the capacitance occurs and triggers an alarm. Although these systems are generally reliable, they can be subject to dust buildup and false alarms in some situations. The newer system, currently in vogue, is a nuclear or radioactive detector. These systems use a shielded Cesium radioisotope to generate a radioactive beam that is received by a detector on the opposite side of the hopper. Ash intercepting the beam decreases the detector signal and triggers a response. This system has two advantages: 1) it does not include a probe that is subject to dust buildup, and 2) more than one hopper can be monitored by one radioactive source. Its major drawback is that plant personnel must deal with a low-level radioactive source, which means adequate safety precautions must be taken. These detectors are provided with safety interlocks to prevent exposure of plant personnel when maintenance is required.

Hopper level detectors normally should be placed between one-half and two-thirds of the way up the side of the hopper. As long as hoppers are not used for storage, this should provide an adequate safety margin. It should be remembered that it takes much longer to fill the upper 2 feet of a pyramid hopper that the lower 2 feet.

Pluggage

Other indirect methods are available for determining whether the hopper is emptying properly. On vacuum discharge/conveying systems, experienced operators can usually tell where the hopper is **plugged** or if a "rat-hole" has formed by checking the time and vacuum drawn on each hopper as dust is removed. On systems that use a screw conveying system, the current drawn by the conveyor motor can serve as an indicator of dust removal. Another simple method for determining pluggage is through a thermometer located approximately two-thirds of the way up on the hopper. If dust covers the probe because of hopper buildup, the temperature will begin to drop, which signals the need for plant personnel to take corrective action.

307 APPLICATIONS OF BAGHOUSES

Baghouses have been used for particulate emission reduction for many industrial applications. Baghouses have been designed to collect particles in the submicron range with 99.9+% control efficiency. They have occasionally been used to remove particles and then recirculate the clean air back into the plant to help supplement heating needs. Baghouses have been used in the chemical, steel, cement, food, pharmaceutical, metal working, aggregate, and carbon black industries. Shaker, reverse air, and pulse jet baghouses have been used in a number of industrial applications as shown in table 307.1.

Table 307.1
Typical Industrial Applications for Baghouses [1]

Shaker	Reverse air	Pulse jet
Screening, crushing and conveying of rock products	Cement kilns	Pharmaceuticals
Low temperature steel applications	Lime kilns	Food industry
Metal working	Electric steel furnaces	Woodworking
Mining operations	Gypsum calcining	Sinter plants
Textiles	Ore smelters and roasters	Metal working
Woodworking processes	Rock dryers	Foundries
Chemical industry	Foundries	Textiles
Food industry	Carbon black	Chemical industry
Coal fired boilers	Magnesium oxide kilns	Coal fired boilers
	Coal fired boilers	Asphalt batch plants

Examples of typical baghouse installations are given in table 307.2. This table lists the industry, exhaust gas temperature, dust concentration, baghouse cleaning method, fabrics, and air-to-cloth ratios. This list is by no means inclusive of the industries using baghouses for controlling particulate emissions. Typical air-to-cloth ratios of shaker, reverse air, and pulse jet baghouses for various industries are also given in table 307.3.

Table 307.2
Typical Baghouse Installations [1]

Industry	Process dust concentration (gr/ft^3)	Baghouse	Fabrics	Temperature (°F)	Air-to-cloth ratio (cfm/ft^2)
Aluminum			Nomex		
furnaces	6 to 20	Shaker	Orlon	250 to 375	2.0 to 2.5 : 1
scrap conveyor		Pulse jet	Polyester	100	7.0 to 8.0 : 1
Asphalt batch plants		Pulse jet	Nomex	250	4.0 to 6.0 : 1
Coal fired boilers (1.5% sulfur coal)		Reverse air	Glass	350 to 450	2.0 : 1
		Pulse jet	Teflon	300 to 450	4.0 : 1
Coal processing					
pulverizing mill		Pulse jet	Nomex felt	240	4 to 6 : 1
dryer		Pulse jet	Nomex felt	400	5 to 7 : 1
roller mill		Pulse jet	Polyester felt	225	6 :1
crusher		Pulse jet	Polypropylene felt	100	7 to 8 : 1
Carbon black		Reverse air	Glass-Teflon treated or Teflon		1.5 : 1
Cement					
clinker cooler		Pulse jet	Nomex felt		5 : 1
crusher venting		Reverse air and shake	Polyester felt, Gore-tex		5 : 1
kiln	10 to 12	Reverse air	Glass	400 to 500	2 : 1
Clay calcining kiln or dryers	25	Pulse jet	Glass felt, Nomex	300 to 400	6 : 1
Copper smelter	< 2	Shaker	Dacron, Teflon	130	
Cupola furnace (gray iron)	1 to 2	Reverse air shaker	Glass-Teflon treated Nomex	550	1.9 : 1

Table 307.2 (contd.)
Typical Baghouse Installations

Industry	Process dust concentration (gr/ft^3)	Baghouse	Fabrics	Temperature (°F)	Air-to-cloth ratio (cfm/ft^2)
Chemical PVC spray dryer		Reverse air	Acrylic Gore-tex	350 to 425	2 to 3.6 : 1
Food sugar storage bin		Pulse jet	Polyester, Gore-tex		10 : 1
Ferro alloy plant silicon metal electric arc furnace	< 1.0	Reverse air with shaker assist	Nomex	350	
Foundry sand casting operation	5 to 10	Pulse jet	Polyester felt	275	6 to 7 : 1
Glass melting furnaces		Reverse air Reverse air and shake	Glass Nomex	400 to 500 375 to 400	< 2 : 1
Gypsum building materials		Pulse jet	Nomex		
Lead smelting (battery lead)		Pulse jet	Nomex, Teflon	320 to 325	
Lime calcining		Pulse jet	Nomex	280	
Metals lead oxide processing		Shaker	Dacron, Gore-tex		1.5 to 3 : 1
Municipal Incinerators	0.5	Reverse air Pulse jet	Glass Teflon	300 300	2 : 1 4 : 1

Table 307.2 (contd.)
Typical Baghouse Installations

Industry	Process dust concentration (gr/ft^3)	Baghouse	Fabrics	Temperature (°F)	Air-to-cloth ratio (cfm/ft^2)
Steel electric arc furnace canopy hood over steel furnace	0.1 to 0.5 0.1 to 0.5 10 or less	Shaker Reverse air Pulse jet	Dacron Dacron Polyester felt	275 125 to 250 250	8 : 1
Secondary copper and brass rotary kiln		Shaker	Nomex	350	
Woodworking furniture manufacturing		Pulse jet	Polyester		10 : 1
Zinc refining coker (zinc oxide)		Pulse jet	Glass felt,	350 to 450	4 to 6 : 1

Table 307.3
Typical A/C Ratios [$(ft^3/min)/ft^2$] for Selected Industries [13]

Industry	Fabric filter air-to-cloth ratio		
	Reverse air	**Pulse jet**	**Mechanical shaker**
Basic oxygen furnaces	1.5 - 2.0	6 - 8	2.5 - 3.0
Brick manufacturing	1.5 - 2.0	9 - 10	2.3 - 3.2
Castable refractories	1.5 - 2.0	8 - 10	2.5 - 3.2
Clay refractories	1.5 - 2.0	8 - 10	2.5 - 3.2
Coal fired boilers	-	-	-
Conical incinerators	-	-	-
Cotton ginning	-	-	-
Detergent manufacturing	1.2 - 1.5	5 - 6	2.0 - 2.5
Electric arc furnaces	1.5 - 2.0	6 - 8	2.5 - 3.0
Feed mills	-	10 - 15	3.5 - 5.0
Ferroalloy plants	2.0	9	2.0
Glass manufacturing	1.5	-	-
Grey iron foundries	1.5 - 2.0	7 - 8	2.5 - 3.0
Iron and steel (sintering)	1.5 - 2.0	7 - 8	2.5 - 3.0
Lime kilns	1.5 - 2.0	8 - 9	2.5 - 3.0
Phosphate fertilizer	1.8 - 2.0	8 - 9	3.0 - 3.5
Phosphate rock crushing	-	5 - 10	3.0 - 3.5
PVC Production	-	7	-
Portland cement	1.2 - 1.5	7 - 10	2.0 - 3.0
Secondary aluminum smelters	-	6 - 8	2.0
Secondary copper smelters	-	6 - 8	-

300 THEORY AND DESIGN

FGD

A relatively new technology for reducing sulfur dioxide (SO_2) emissions from combustion sources is using dry flue gas desulfurization (**FGD**). In dry FGD, the flue gas containing SO_2 is contacted with an alkaline material to produce a dry waste product for disposal. This technology includes:

ESP

- Injection of an alkaline slurry in a spray dryer with collection of dry particles in a baghouse or electrostatic precipitator (**ESP**);

- Dry injection of alkaline material into the flue gas stream with collection of dry particles in a baghouse or ESP;

- Addition of alkaline material to the fuel prior to combustion.

These technologies are capable of SO_2 emission reduction ranging from 60 % to 90 % depending on whicn system is used.

308 REVIEW OF DESIGN CRITERIA

The design of an industrial baghouse involves consideration of many factors including space restriction, cleaning method, fabric construction, fiber, and air-to-cloth ratio; and many construction details such as inlet location, hopper design and dust discharge devices. Air pollution control district personnel who review baghouse design plans should consider these factors during the review process.

A given process might often dictate a specified type of baghouse for particulate emission control. The manufacturers' previous experience with a particlular industry is sometimes the key factor. For example, a pulse jet baghouse with its higher filter rates would take up less space and would be easier to maintain than a shaker or reverse air baghouse. But if the baghouse was to be used in a high temperature application (500 °F or 260 °C), a reverse air cleaning baghouse with woven Fiberglas bags might be chosen. This would prevent the need for exhaust gas cooling for the use of Nomex felt bags (on the pulse jet unit), which are more expensive than Fiberglas bags. All design factors must be weighed carefully in choosing the most appropriate baghouse design.

The principal design is the gas flow rate to the baghouse, measured in cubic meters (or cubic feet) per minute. The gas volume to be treated is set by the process exhaust, but the filtration velocity or air-to-cloth ratio is determined by the baghouse vendor's design. The air-to-cloth ratio depends on a number of variables. A thorough review of baghouse design plans should consider the factors described below.

Physical and chemical properties, such as type, shape, and density of dust. Also average and maximum concentrations; chemical properties such as abrasiveness, explosiveness, electrostatic charge and agglomerating tendencies. These are important in selecting the fabric that will be used. For example, abrasive dust will deteriorate fabrics such as cotton or glass very quickly. If the dust has an electrostatic charge, the fabric choice must be compatible to provide maximum particle collection yet still be able to clean the bags without damaging them.

Gas flow rate -- average and maximum flow rate, temperature, moistrue content, chemical properties such as dew point, corrosiveness and combustibility. If the baghouse is going to be installed in an existing source, a stack test should be performed to determine the process gas stream properties. If the baghouse is being installed on a new source, data from a similar plant or operation may be used, but the baghouse should be designed conservatively. Once the gas stream properties are known, the designers will be able to determine if the baghouse will require extras such as shell insulation, special bag treatment, or corrosion-proof coatings on structural components.

Fabric construction: woven or felt filters, filter thickness, fiber size, fiber density, filter treatments such as napping, resin and heat setting, and special coatings. Once dust and gas stream properties have been determined, filter choice and special treatment of the filter can be properly made. For example, if the process exhaust from a coal fired boiler is 400 °F (204 °C), with a fairly high SO_x concentration, the best choice might be to go with woven glass bags that are coated with silicon graphite.

Fiber type: natural, synthetic, Nomex, Teflon, etc. The design should include a fiber choice dictated by any gas stream properties that would limit the life of the bag.

Proper air-to-cloth-ratio: reverse air allow the lowest, shakers next, and pulse jet baghouses the highest A/C ratio.

Cleaning methods: low energy which are shaker and reverse air cleaning; high energy which is pulse jet cleaning. The cost of the bag, filter construction, and the normal operating pressure drop across the baghouse help dictate which cleaning method is most appropriate.

Cleaning time: Ratio of filtering time to cleaning time is the measure of the percent of time the filters are performing; this should be at least 10:1 or greater. For example, if the bags need shaking for two minutes every 15 minutes they were on line, the baghouse shold be enlarged to handle this heavy dust concentration from the process.

Cleaning and filtering stress: amount of flexing and creasing to the fabric; reverse air is the gentlest, shaking and pulse jet have the most vigorous stress on the fabric. For example, it would probalbly not be advisable to use woven glass bags on a shaker or pulse jet baghouse.

Bag spacing: Bags must be properly spaced to eliminate rubbing against each other; bags must be accessible for inspection and maintenance service. The design should include access ladders, walkways, and doors to get at bags for periodic inspection and replacing.

Compartment design: allowance for proper cleaning of bags; design should include an extra compartment to allow for reserve capacity and inspection and maintenance of broken bags. Shaker and reverse air cleaning baghouses that are used in continuous operation require an extra compartment for cleaning bags while the other compartments are still online (filtering).

Space and cost requirements: Baghouses require a good deal of installation space; initial costs, and operating and maintenance costs can be high. Bag replacement will average between 25 and 50 % of the original number installed per year. This can be very expensive if the bags are made of Teflon.

Emission requirements: that is, efficiency in terms of opacity and grain-loading regulations. Baghouses are very efficient; collection efficiency is usually greater than 99^{+} %.

308.1 REVIEW EXERCISE 1

Baghouse sizing is done by the manufacturer. A simple check or estimate of the amount of baghouse cloth needed for a given process flow rate can be computed by using equation 304.4:

$$v_f = Q/A_c \qquad \text{or} \qquad A_c = Q/v_f$$

where:
- A_c = cloth area
- Q = process exhaust rate
- v_f = filtration velocity

For example, the process gas exhaust rate is given as 4.72×10^6 cm^3/sec (10000 ft^3/min) and the filtration velocity is 4 cm/sec (A/C is 4:1 (cm^3/sec)/cm^2).

Calculate the cloth area.

$$\begin{aligned} A_c &= (4.72 \times 10^6 \text{ cm}^3\text{/sec})/(4 \text{ cm/sec}) \\ &= 1{,}179{,}875 \text{ cm}^2 \text{ (cloth required)} \\ &= 118 \text{ m}^2 \text{ (cloth required)} \end{aligned}$$

To determine the number of bags required in the baghouse, one would simply use the formula:

$$A_b = \pi dh$$

Where:

A_b = area of bag, m^2 (ft^2)
$\pi = 3.142$
d = bag diameter, m (ft)
h = bag height, m (ft)

The bag diameter is 0.203 m (8 in) and the bag height is 3.66 m (12 ft).

Calculate the area of each bag.

$$\begin{aligned} A_b &= 3.142 \times 0.203 \text{ m} \times 3.66 \text{ m} \\ &= 2.33 \text{ m}^2 \end{aligned}$$

Calculate the number of bags in the baghouse.

$$\begin{aligned} \text{Number of bags} &= (117.98 \text{ m}^2)/(2.33 \text{ m}^2) \\ &= 51 \text{ bags} \end{aligned}$$

A very important point to remember is that the bag length may not be exactly that given in the published specifications. For example, most 12 inch diameter bags are 11 5/8 inches in diameter. The effective filtering area should be calculated using the exact bag dimensions.

308.2 REVIEW EXERCISE 2

The Joe Magarac Steel Company is planning to install two 150-ton electric steel furnaces. The furnaces will be charged with molten iron and cold scrap. The company is installing a baghouse to control particulate emissions. The pertinent process and baghouse data is given below. The main question here is: should this plan for construction of this air pollution source be approved by the APCD permit engineer?

Process Information

Process equipment: two 150-ton 3-phase electric arc furnaces

Operating schedule: 24 hours/day, 7 days/week, 52 weeks/year

Exhaust gas termperature: at canopy hood and furnace tap = 2730 °F

Exhaust gas conditioning: water cooled by evaporation and air dilution

Exhaust gas volume handled: 2,290,000 acfm at 150 °F (total from both furnaces)

Inlet dust concentration (to baghouse): 1.5 to 5.0 gr/dscf

Particle size date:

Size (µm)	Percent (%)
>44	7
20-44	7
10-20	6
5-10	8
<5	72

Baghouse Information

Positive pressure baghouse

Reverse air cleaning:	from a separate fan, 48000 cfm @ 15 in. H_20, 70 °F
Air-to-cloth ratio:	3:1
Pressure drop:	6 to 8 in. H_2O
Bags:	34.7 ft long, 11.75 in diameter
Fabric:	Dacron woven bags, silicon treated
Compartments:	34
Bags/compartment	228
Dust/outlet concentration	0.0052 gr/dscf
Collection efficiency:	99.77%

Solution

The particle size data shows that the selection of baghouse is very good since the majority of the particles are very small (<5 μm) in diameter. The exhaust volume to the baghouse is 2,290,000 (total from both furnaces) at 150 °F. The air-to-cloth ratio is 3:1.

1. To determine the cloth area needed, use the formula:

$$A_c = Q/v_f$$

Then
$$A_c = (2{,}290{,}000\ ft^3/min)/(3\ ft/min)$$
$$= 763{,}334\ ft^2$$

2. To determine the area of the bags required in the baghouse, use the formula:

$$A_b = \pi dh$$

Where: A_b = area of bag, ft^2
$\pi = 3.14$
d = bag diameter, ft
h = bag height, ft

Then: $A_b = 3.14 \times (11.75/12)\ ft \times 34.7\ ft$
$= 106.7\ ft^2$

3. To calculate the number of bags needed in the baghouse:

$$\text{Number of bags} = A_c/A_b$$
$$= 763{,}334\ ft^2/(106.7\ ft/bag)$$
$$= 7154 \text{ bags}$$

4. There are 228 bags per compartment. A good baghouse design would include 2 extra compartments: 1 for bag cleaning, and 1 for bag maintenance.

$$\text{Number of compartments} = \frac{\text{Number of bags}}{\text{(Number of bags per compartment)}}$$

$$= 7154 / 228$$
$$= 31.3$$

Since it is impossible to have a partial compartment, the design should have 34 compartments; 32 for filtering, 1 for cleaning, and 1 for maintenance.

5. From tables 304.1 and 307.3, the air-to-cloth ratio of 3:1 seems to be reasonable.

6. From table 303.1, woven Dacron bags can withstand continuous temperatures upto 275 °F or 135 °C. Since the gas temperature to the baghouse is less than 150 °F, then the use of Dacron bags is fine.

7. The agency should require that the source owner submit an operation and maintenance schedule that will help keep the baghouse on-line.

8. It appears that this baghouse construction plan meets design criteria. This plan should be approved.

308.3 REVIEW EXERCISE 3

The Cheeps Brewing Co. is planning to install a coal fired industrial boiler for producing process steam and heat. The boiler information and control equipment data are given below. Should this plan be approved by the air pollution control agency?

Boiler information

1 pulverized coal fired boiler

Heat input:	152×10^6 Btu/hr
Coal:	sulfur content 2 % ash content 10 % heat content 13,000 Btu/lb
Operating schedule:	24 hours/day, 7 days/week, 40 weeks/year
Exhaust gas volume:	48,000 acfm
Exhaust gas temperature:	360 to 390 °F
Inlet dust concentration (to baghouse):	10 gr/scf

Particle size data:

Size (μm)	Percent (%)
>60	5
20-60	7
10-20	20
5-10	30
<5	38

Baghouse Information

Negative pressure baghouse

Pulse jet cleaning:	4 compartments
Air-to-cloth ratio	4.5:1
Pressure drop:	6 in. H_2O
Bags:	12 ft long, 5 1/4 in. diameter
Fabric:	23 oz. Teflon felt
Number of compartments:	5
Number of bags per compartment:	144

The baghouse is insulated to prevent condensation. Dust is removed from the hopper by a pneumatic conveyor.

Stack height:	89 ft
Stack diameter	4 ft 6 in
Fan (induced draft):	100 hp and 580 rpm

Solution

From examining the boiler and baghouse data a number of points can be made.

1. The choice of fabric material used to make the bags can be obtained from table 303.1. A logical choice can be one of the following since the gas temperature is 360 to 390 °F:

   - glass bags
   - Teflon bags
   - Nomex bags

Using Nomex bags would probably be ruled out because the sulfur content is 2 % and the sulfur oxides and acids formed destroy this material (see table 303.2). Glass bags could be used for this unit. Teflon bags would also be a good choice with the only deterrent being their high cost.

2. The air-to-cloth ratio can be checked from table 304.1. For a pulse jet baghouse an air-to-cloth ratio of 4.5:1 (cfm/ft^2) is well within the limits of the typical range. The use of a pulse jet baghouse will also enable the designer to push the air-to-cloth ratio a little higher than if a reverse air baghouse with woven glass bags were used.

3. The exhaust gas volume is 48,000 acfm at 360 to 390 °F. The air-to-cloth ratio is 4.5:1. Calculate the cloth area.

$$A_c = Q/v_f$$

$$A_c = \frac{48{,}000 \text{ ft}^3/\text{min}}{4.5 \text{ ft/min}}$$

$$= 10{,}667 \text{ ft}^2$$

4. Calculate the bag area:

$$A_b = \pi dh$$

$$A_b = 3.14 \times (5.25 / 12) \text{ ft} \times 12 \text{ ft}$$

$$= 16.49 \text{ ft}^2$$

5. Calculate the number of bags needed:

$$\text{Number of bags} = A_c / A_b$$

$$\text{Number of bags} = 10{,}667 \text{ ft}^2 / 16.49 \text{ ft}^2$$

$$= 647 \text{ bags}$$

6. There are 144 bags in each compartment. The design plan calls for 5 compartments, which give a total of 720 bags. This would be adequate in

terms of filtering the fly ash. If one compartment needed maintenance, the gas flow rate into the other four would be higher, pushing up the air-to-cloth ratio. Maintenance could also be performed during scheduled boiler down time, or by reducing the steam load to approximately 80 %. An operation and maintenance schedule should be included in the design plan.

7. This baghouse is a negative pressure system with an induced draft fan, 89 foot stack and 4.5 foot stack diameter. This unit could easily be tested for compliance and the air district must request a stack test before issuing a permit to operate.

8. This plan should be approved.

400 INSPECTIONS

Compliance Determination Methods

There are four ways that the **compliance** status of a source can be predicted or measured: inspections, engineering evaluations, source testing and continuous emission monitoring. Of these, only the second two provide actual emission data as to the extent of emissions from a facility. Inspections, source testing and continuous emission monitoring are addressed in this chapter.

Air pollution control district inspectors inspect baghouses on a regular basis. Baghouse operators must do the same, as part of a formal maintenance program, in order to ensure that their units are operating at design or near-design efficiencies. This chapter is written for both audiences.

Reasons for Inspections

Baghouse **inspections** by air pollution control agencies may be performed for any one of the following **reasons**: compliance determination, complaint investigation as a result of excess emissions or equipment malfunction, source plan approval, permit review/renewal, and special studies. Examples of special studies would be operating and maintenance evaluations, or updating emission inventories. The type and purpose of the inspection will determine:

1. The extent of preparation for the inspection;
2. Whether or not the inspection is announced;
3. The effort and/or time required for conducting it.

Compliance-type inspections provide preliminary assessments only, since source testing is the definitive measure for determining compliance with the emission standard. These inspections should usually be unannounced so that the plant can be evaluated under its normal operating conditions. Such indicators as fuel use, continuous monitoring facilities, and visible emissions, which can be estimated during an unannounced inspection, often provide a definitive picture of a plant's manufacturing and baghouse operations, provided there are no plant access problems or faulty and/or inoperative equipment.

For other inspections pertaining to source construction, plan approval, or permit to operate, the plant should be given sufficient advance notice so that qualified plant personnel can be present to provide the drawings, manuals, and process information that may be required. Prior notice should also be given when performing inspections for special studies designed to document operating and maintenance practices, or process and emission data. This will allow the operator time to make readily available information such as raw material rates, production levels, and stack test results. Regardless of the type of inspection to be conducted, pertinent supporting information should be obtained prior to, during, and following the source evaluation.

400 INSPECTIONS

Safety procedures to be observed when planning to enter a baghouse are outlined in section 603 of the Maintenance chapter.

Appendix D

A sample pre-inspection worksheet and inspection checklist are provided in **appendix D**.

401 PRE-INSPECTION

Plant History

A logical starting point for regulatory inspectors in the inspection process is to review the **files concerning the specific plant.** Construction and operating permits and pending compliance schedules pertaining to source processes should be studied. The inspector should also obtain copies of breakdown records and any reports about past noncompliance, so as to know the frequency of various malfunctions reported, the history of abnormal operations (including operation while under variance), and past conditions and causes of noncompliance.

The inspector should prepare a concise file containing basic plant information, process descriptions, flowsheets, and acceptable operating conditions. It should contain the following to facilitate inspections and/or preparations:

1. A chronology of control actions, inspections, and the complaints concerning each major source in the plant;

2. A flowsheet identifying sources, control devices, monitors, and other information of interest;

3. The most recent permits for each major source;

4. Previous inspection checklists;

5. A set of process operating conditions, fan characteristics, and raw material characteristics;

6. A set of general arrangement drawings of the control equipment, ventilation system layout, and waste handling system.

The inspector should select a time to inspect the plant when the processes will be operating at representative conditions. This is especially important in the case of operations with seasonal schedules.

401.1 INSPECTOR EQUIPMENT

The following tools and safety gear should be carried in a portable case from source to source. The inspector should have these available at all times.

Hardhat
Safety glasses or goggles
Gloves
Coveralls
Steel tipped safety shoes
Ear protectors
Tape measure
Flashlight
Manometer or differential pressure gauge
Stopwatch
pH paper
Duct tape
Pry bar
Pocket calculator
Pocket guide of industrial hazards
Polaroid camera
Compass

The following pieces of equipment can be left in a central location until needed:

Respirator with appropriate cartridge
Velometer
Pump and filter system
Bucket
Combustion gas analyzer
Thermometers or thermocouples
Multimeter
Sample bottles
Strobe
Inductance ammeter
Tachometer
Oxygen and combustibles meter
Self-contained breathing equipment
Pipe wrench
Rope

400 INSPECTIONS

Safety

Particularly important is the **safety** equipment. It is the inspector's responsibility to have safety equipment before entering the plant. Access to certain industrial facilities can be rightfully restricted or refused by plant representatives if designated equipment is not worn.

402 PRE-INSPECTION INTERVIEW

Operational Changes

The inspector should discuss the purpose of the inspection with the appropriate plant official. Any changes in plant management should be noted. The inspector should ask questions relating to the process and the baghouse to determine whether information from the file on the facility still pertains. Listed below are questions an inspector might ask about process operational changes and **changes in baghouse operation**. See also table 402.1.

1. Has the rate of production increased or decreased?

2. Has there been a change in the product mix? (For example, in a cement plant, this would include a change in the moisture content of the slurry.)

3. Have operating temperatures changed? (This can result from the addition of energy conservation retrofits. Examples are the addition of economizers to a boiler, the addition of air or raw material preheaters in a molten metal process, or the addition of more chains in the kiln in a cement process.)

4. Have there been changes in startup or shutdown procedures?

5. Have there been any changes such as the addition of new forced-draft fans or new induced-draft fans? Any addition or removal of afterburners?

6. Has there been any change made in the use of collected dust in the process, such as re-injection or return of the dust to the raw material mix?

7. Has the amount of excess air been changed? Has the soot blowing schedule been revised?

8. Has the effective size of the dust collector been changed?

9. Have new sources of emissions been added to the baghouse?

10. Have any retrofits been added or removed in the baghouse system?

11. Have there been any changes in the dust removal system, new dust conveying equipment or arrangement of dust conveyors, vacuum/pressure system changes, evacuation sequence changes, combination or isolation of dust removal sytstems from several units?

Table 402.1
Baseline Test Information

Process Conditions	Gas flowrate Gas temperature - point A, B, C, etc. Static pressure Process level (load, % capacity) Process feed rate(s) Process feed descriptor(s) Process product level(s) Process product descriptor(s)
Baghouse Operating Conditions	Gas temperature, baghouse inlet(s) Gas temperature, baghouse outlet(s) Pressure drop across bags

403 INSPECTION SEQUENCE

The purpose and type of the proposed inspection, coupled with visible emission observations made while outside the facility, will suggest whether the process equipment or the baghouse should be inspected first.

Reasons for proceeding immediately to the baghouse would be as follows:

- Observations made outside the plant indicate significant stack or fugitive emissions;

- The inspection is a strict, unannounced compliance-type;

- Plant personnel are suspected of tampering with several facets of the baghouse operation; or

- The inspector, because of numerous visits to the plant, is very familiar with the process operation, and does not intend to do any extractive sampling.

Reasons for beginning the inspection with the process equipment would be the following:

- An unannounced, noncompliance-type inspection is being performed and the inspector is assured that the baghouse will be completely operational, and the inspector is unfamiliar with some process details and would like to observe it before seeing the baghouse in operation.

Regardless of where the inspection begins, once inside the plant (the stack and plant surroundings should be evaluated prior to entering the facility), the inspector should proceed in a logical sequence from one end to the other. In this manner the inspector can grasp the total picture and thus have a better appreciation of potential problems, their causes, and possible solutions. A logical **approach** to an inspection would include the following steps in the given sequence.

9-Step Approach

1. Observe the stack effluent and plant environs
2. Check the continuous emission monitors
3. Measure the fan operating parameters
4. Record and evaluate baghouse parameter monitor readings

5. Inspect the baghouse exterior
6. Inspect the dust capture system
7. Evaluate process conditions
8. Inspect the interior of the baghouse
9. Review operating records

Details for the inspection steps are given in sections 403.1 through 403.9.

403.1 OBSERVE THE STACK EFFLUENT

Opacity readings of emission points should be made using Method 9 procedures. Opacity readings can be used for more than determining the compliance status of the effluent with the opacity standards. They can also be used to diagnose changes in system performance. This is described in the following paragraphs.

In most cases, there is a relationship between the opacity observed during the inspection and the mass emissions penetrating the control device. Regardless of the mathematical form of this relationship, as opacity increases, the mass emissions generally increase.

In figure 403.1, Case 1 represents the most sensitive relationship—a small increase in opacity indicates a large increase in mass emissions. However, errors inherent in a small opacity increase can make any conclusions meaningless in this case.

Opacity vs. Mass Emissions

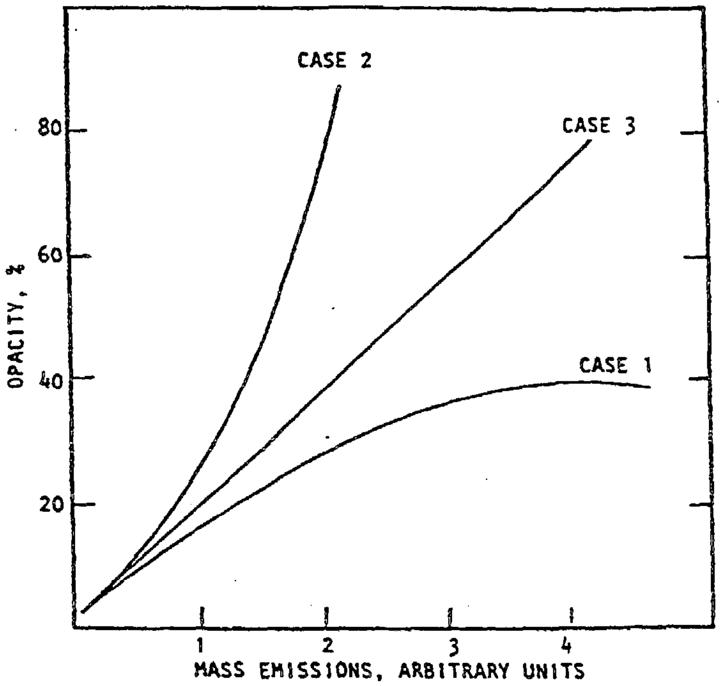


Figure 403.1 Opacity-Mass Relationships [14]

Case 2 presents "contrary" problems—above a certain upper opacity level, there is no change in upper opacity rates. At this level, opacity has no diagnostic value. The ideal case is the linear relationship of Case 3, which is generally the prevailing relationship in most industries.

Mass emission regulatory limits and opacity limits may not always agree. Linear relationships in figure 403.2 illustrate these possible disagreements. Case 4 represents the intended situation, where any violation of an opacity regulation also involves a violation of the mass emission regulation. In Case 5 there is a substantial opacity violation without a violation of the mass standard. In other cases (represented by line segment 6), a violation of mass emission standards might not be suspected due to decreased sensitivity to opacity. The point is that in certain cases, the absolute magnitude of the observed opacity is most useful when the opacity-mass relationship is known.

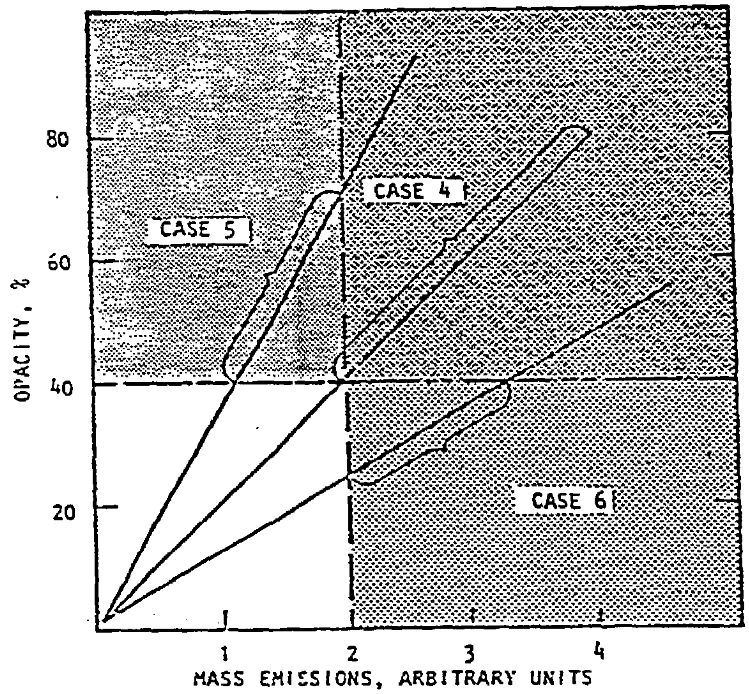


Figure 403.2 Opacity and Mass Emission Violations [14]

Regardless of the opacity-mass relationship, a change in opacity does indicate a change in mass emissions.

Plume Color

The color of the effluent is another plume characteristic which should be observed. For fossil fuel combustion sources, the color is an indirect indication of operating conditions. Table 403.1 shows causes for various colors of **plumes**.

Table 403.1
Plume Characteristics and Combustion Parameters

Plume Color	Possible Operating Parameters to Investigate
White	Excess combustion air; loss of burner flame in oil-fired furnace
Grey	Inadequate air supply or distribution
Black	Lack of air; clogged or dirty burners or insuffficient atomizing pressure, improper oil preheat
Reddish brown	Excess furnace temperatures or excess air; burner configuration
Bluish white	High sulfur content in fuel

For other types of sources, the color may not be as variable or may not have a distinct meaning with respect to the process or the control equipment. Nevertheless, a change in the color indicates a change in the system. For example:

1. Increased quantities of bluish particulates generally indicate increased generation of very small particles (0.1 to 2 microns) which are difficult to collect in most control devices.

Vapors

2. A detatched plume demonstrates fairly conclusively that particulates are forming as the **vapors** are released to the cold ambient air. Detatched plumes often cause serious corrosion problems, since any cold surface in the system is susceptible to acid-mist condensation.

Puffs

3. Frequently occurring, short duration "**puffs**" from the stack may indicate a defective cleaning system, insufficient compartmentalization, too small an interval between cleanings, or a defective baffle in one compartment. Cyclic process conditions can also lead to puffs.

Upon arrival at the general plant location (but probably beyond plant boundaries), the stack(s) should be observed for visible emissions. With properly operating baghouses, no visible emissions (less than 5 percent opacity) should be the rule. Depending on the general plume appearance and whether the inspector is a certified smoke reader, a detailed Method 9 evalualtion may be justified. Section 201 has a discussion on the procedure for data reduction, using a three-minute aggregate of excessive opacity readings.

In addition to monitoring any smoke emissions, the plant environs should be checked for fugitive emissions, dust deposits, or damage to vegetation, any of which may indicate nonoperative or malfunctioning baghouse equipment. After the plant surroundings have been observed for whatever length of time is deemed necessary (10 minutes to 30 minutes usually), the inspector should enter the property.

403.2 STEP 2: CHECK THE CONTINUOUS EMISSION MONITORS

After observation of the stack effluent, the next step is to check the continuous emission monitors (transmissometers) downstream from the control equipment. This involves:

1. Checking the operation of the purge air blowers and the alignment of the source and retro-reflection;

2. Comparing the actual path length with the value used in the instrument calibration;

3. Checking the zero and full scale settings without taking the instrument offline, if possible;

4. Checking the status of the window inductor light;

5. Studying the instrument recording trace with a view to changes in recorded values, which may indicate that the transmissometer is operating unreliably.

Process operating personnel should be able to provide information on the technique and the frequency of calibrations.

Confirm Opacity Observations

The transmissometer data should be able to confirm and clarify the **opacity observations** made by visual evaluation of the stack(s). Instrument problems should be suspected when there are substantial differences between the opacity recorded in Step 1 and that indicated on the monitor. If the instrument response time and the recorder chart speed have been set properly, it will be possible to check for trends in the opacity levels.

A cyclic pattern suggests variation in process operating conditions.

A continually deteriorating pattern suggests a developing problem in the baghouse, which is likely to demand the attention of the inspector. A deterioration can also suggest, on the other hand, a gradual drift of the instrument or accumulation of dirt on the optical surfaces.

Failure to operate and/or maintain an opacity monitor can constitute a violation of regulations.

In Step 2, the inspector should have:

1. Confirmed the visible emissions status with respect to opacity regulations;

2. Confirmed the installation and operating status with respect to continuous monitor regulations;

3. Developed a preliminary idea of the process and the baghouse operating conditions.

As yet, there would not be enough information to evaluate mass emissions in cases where a reliable opacity-mass emission correlation has not been identified.

403.3 STEP 3: MEASURE THE FAN OPERATING PARAMETERS

Three operating parameters of the induced draft fan are useful in interpreting control system operations. They are:

1. Increase in total static pressure across the fan;

2. Electrical current drawn by the fan motor;

3. Revolutions per minute (rpm) of the fan wheel.

Gas Flowrate

Evaluated together, these parameters indicate the **gas flow rate** and the total system pressure drop. These changes are important in diagnosing control system operating conditions. If the inspector has performance curves for the fan, he can use these parameters to find the gas flow rate through the fan from the fan curves. However, even without the fan charts, the inspector can use the above three parameters by comparing the measured values with the baseline values.

If the fan parameters are not monitored at the plant, the inspector should use an inductance ammeter to measure motor current, a manometer (or magnehelic gauge) to measure fan static pressure, and a tachometer (or a strobe in cases where the tachometer cannot be used) to measure fan speed. The inspector should request that static pressure taps be made in the ductwork leading to and from the induced draft fan. The inspector should not drill or cut these holes unless the plant manager approves. Once taps are available, the static pressure at the fan inlet and outlet should be measured using the set of magnehelic gauges.

At the end of Step 3, the inspector should decide whether or not further on-site efforts are necessary to determine compliance with mass emission standards. If the fan operating parameters (static pressure, motor current, and rpm) are within plus or minus 10 percent of baseline values and if the gas temperature at the fan inlet is within 20 °F, it is unlikely that mass emissions have changed significantly. Generally, it is necessary to inspect the control equipment to confirm the evaluations already made.

Air Inleakage

A second purpose of the fan inspection is to determine if serious **air inleakage** is occurring and if this is compromising pollutant capture efficiency back at the source. This problem is confirmed by measuring flue gas oxygen levels. The O_2 and CO_2 levels at the inlet and outlet of combustion source baghouses should be checked. The measurement point on the inlet must be between the solids discharge valve and the tubesheet, so that potential inleakage at this point can also be taken into account. There should not be more than a 1% rise in the oxygen levels going from the inlet to the outlet (eg., 6% O_2 in and 7% O_2 out). Reduced gas temperature and increased fan current further support air inleakage checks.

403.4 RECORD AND EVALUATE BAGHOUSE PARAMETER MONITOR READINGS

For most baghouses, the two most useful operating parameters are the opacity and the pressure drop across the filter material. In some applications, temperature data will be important for evaluation of the impact of high temperature excursions or condensation.

To be of greatest value, these parameters must be compared against initial design conditions or baseline values to determine their acceptability. For example, measurement of temperature and pressure drop has little meaning if the design and baseline values of these parameters are not known. The temperature limits may be set by dewpoint conditions and by bag type, both of which are part of the design and baseline criteria data set. Without this data, the value recorded for temperature has relatively little meaning. A similar case can be made for pressure drop. Thus, a comparison of the key operating parameters with design or baseline values provides an awareness of what values are "normal" or fall within the range of acceptable performance.

Pressure Drop

The **pressure drop** across a baghouse gives an indication of the resistance to gas flow and cleaning effectiveness. Any changes in the pressure drop, whether gradual or sudden, may indicate the need for maintenance.

The pressure drop across the collector should be noted. If there is a gauge, proper operation of the gauge should first be confirmed by observing meter response during the pulsing cycle for pulse-jet baghouses. In shaker collectors, the pressure drop during compartment cleaning should be zero. Non-zero values may also indicate damper leakage problems. In reverse-air collectors, backflow will cause a measureable pressure drop with a polarity opposite that of the filtering cycle.

If a properly operating gauge is not available, the static pressure drop should be made with portable instruments. These measurements should be made at isolated ports installed specifically for the use of portable instrumentation. It is important to make the measurements on the inlet and the outlet one at a time so that plugged tap holes and lines can be identified.

Temperature

If no gauge is available and the unit operates at an elevated gas **temperature**, the gas temperature should be measured. This can be done at a point on the inlet duct to the collector or at one of the tap holes (if direct access to the interior of the collector is possible.)

Compressed Air Pressure

Reverse Air Pressure

The **compressed air pressure** and reverse air pressure should be measured and compared with baseline values. If compressed-air pressures are too high, especially for units designed with high air-to-cloth ratios, the intense cleaning action could result in some seepage of dust through the bag fabric immediately after cleaning, when the bag is pushed into the support cage. This will cause a momentary puff of 5 to 10 percent opacity.

Volume Flow

The inspector should also check and record any monitors for **volume flow** and moisture. Air-to-cloth ratios can be calculated from these values. These should be compared with baseline values.

The inspector should also check cleaning sequence and intervals for the baghouses, using the manufacturer's specifications as a guideline.

403.5 INSPECT THE BAGHOUSE EXTERIOR

The overall condition of the exterior housing should be noted. The inspector should check structural members and access doors and gaskets. Corrosion, warping of panels, faulty or missing gasketing, and loose bolts are visually identifiable. Unusual noises, odors, and elevated temperatures can be indicative of worn bearings, overstressed fan belts and electric motor problems.

Valve Operation

The operation of the cleaning system in pulse-jet baghouses should be checked by noting the air reservoir pressure. The ends of the reservoir and the connections to each of the diaphragm valves should be checked for air leakage. Because these valves are normally activated on a frequent basis, it is usually possible to observe a complete cleaning cycle. Each valve should generate a crisp thud when activated. Valves that fail to activate or that produce a weak sound when activated are usually not working properly. If too many of these valves are out of service, the air-to-cloth ratios are probably high, which can cause excessive emissions through the baghouse or inadequate pollutant capture. Even if all diaphragm valves are working properly, reduced cleaning effectiveness can result from the low compressed-air pressures.

The compressed air system should be inspected to determine whether it contains any water or rust deposits that could cause the system to malfunction. One quick method of checking whether the system has water or rust deposits is to carefully open the valve on the blowdown system and observe whether any water or other material is being expelled through the valve. Also, if the system has oil traps, the traps can be visually inspected to determine if any water or other material is retained in the trap.

Inleakage

The inspector can check for air leakage by listening for the sound of inrushing air.

403.6 INSPECT THE DUST CAPTURE SYSTEM

The discharge of solids should be observed if this can be done safely and conveniently. In a pulse jet baghouse, solids are discharged on a fairly continuous basis (following each pulsing of a row). In reverse air and shaker type baghouses, solids are usually discharged only at the beginning of the cleaning cycle in each compartment.

Level Alarms

Temperature

Inspectors should check to see that the evacuation rate for the hoppers is quick enough to prevent buildup of dust over any of the hoppers. If **level alarms** are used, the inspectors should determine that these are operating properly. The inspector should also check the **temperature** of the hoppers relative to each other. This can be done simply by touching each hopper throat with the back of the hand. If collected matter is allowed to cool, it becomes more prone to form bridges and plug up the inside of the hopper.

Dust Evacuation

Problems the inspector should look for in the **dust evacuation** and removal system include dust buildup beneath the baghouse, holes or leaks, proper operation of the discharge screw, disengagement of vacuum connections, malfunction of rotary air lock valves, and failure of sequencing controls.

Also to be evaluated are use of movable or stationary hoods, capture velocities, condition of cleanout traps, length of runs to baghouse, and leaks or fugitive dust emissions.

403.7 EVALUATE PROCESS CONDITIONS

The inspector should proceed to check a number of process parameters that can affect baghouse performance. If possible, the following readings should be taken:

- Process weight;

- Gas flow rate;

- Gas velocity;

- Excess air;

- Gas temperature;

- Moisture content of flue gas;

- Flue gas analysis (O_2, CO_2, etc.);

- Soot blowing intervals.

Many of these instruments are located in the process control room and have continuous readouts. Variations in readings from process instruments from the normal design ranges should be investigated as to their possible effect on baghouse performance.

403.8 INTERNAL INSPECTION (OPTIONAL)

Unless it is deemed absolutely necessary, the inspector should not request the plant to shut down their process/fabric filter system so that an internal inspection of the fan and baghouse can be made. If an internal inspection is required, it is usually advisable to wait for a scheduled plant shutdown.

If a baghouse is down for scheduled maintenance or because of a malfunction, and an inspection is being performed, the inspector should take time to perform some checks in addition to those already mentioned. These techniques are covered in section 603.4 of this manual. The regulatory inspector should focus on those fields already identified as trouble spots in previous steps of the inspection.

Safety Measures

Before attempting to perform an internal inspection, personnel should ensure that all proper **safety measures** are observed. Section 603.2 describes some necessary safety tests.

The following procedures can be used to view the interior of a baghouse without actually entering the unit.

For a top-access pulse-jet system, the possibility of fabric blinding can be checked from the top access hatch. Oil and water in the compressed air line are sometimes partially responsible for the blinding that takes part of the fabric out of service.

Blinding

For conventional pulse-jet collectors, the possibility for **blinding** can only be checked at the dirty-side access hatch. A crusty cake is evidence of excessive moisture or sticky deposits on the bags.

Both types of pulse-jet collectors can experience possible premature bag failure at the bottom. This can be checked from a dirty-side access hatch, or in some cases from below (using extreme caution). Note that only the operator should open the hatches at the tops of hopper areas. Hot solids can flow rapidly out of these hatches.

Fluorescent Dye

The presence and nature of the clean-side deposits should be checked by viewing conditions from the access hatch. Note that the compartment must be isolated by the operator before attempting to do the internal inspection. Even slight dust deposits on the clean side can be a sign of major problems. Dust near one or more bag outlets may suggest inadequate sealing of the tube sheet. Holes and tears may disperse dust throughout the top side of the tube sheet and make it difficult to identify the bag with the hole. Fluorescent dye **may be used later to identify the problem.**

403.9 REVIEW OF OPERATING RECORDS

Violations

The inspector should review operating records from the process and the baghouse, both for completeness and for changes in operation that may have affected baghouse performance. The records actually required from a regulatory standpoint will vary from plant to plant. The inspector should keep in mind that failure on the part of an operator to keep required records constitutes a **violation** of either air pollution regulations or permit conditions.

Bag Failure Records

The inspector should request to see equipment operation and maintenance logs to evaluate such entries as: location of failed bags; bag replacement frequency; cause of **bag failure** (blowout, tears, chemical attack, abrasion, pinholes); where on the bag failure usually occurs (top, middle, at the cuff, along the seam); or other types of recurring problems with the system that may be suggestive of a trend that should be carefully watched.

Spare Parts

It should also be noted whether **spare parts** (bags and associated accessories such as clamps, J-hooks, springs, rings, cages, etc., and fan belts, motors, gaskets, bearings, solenoid valves, etc.) are kept on hand or whether the plant must order new parts each time service is required.

Legitimate Breakdowns

Diagnostic records should be reviewed to confirm that reasonable attempts to reduce the frequency of malfunctions have been made. If the source has reported as "breakdowns" any baghouse malfunctions that could have been avoided through regular maintenance practices, these do not meet the conditions to qualify as a **legitimate breakdown** per the district rule. Appropriate enforcement action should be taken.

Accurate recordkeeping, which is a vital part of a good preventive maintenance program, can greatly aid the baghouse manufacturer in solving field problems. Although it is usually recommended that the user follow the manufacturer's guidelines regarding inspection and maintenance frequency, it is not uncommon to find plant logs reflecting deviations from vendor-recommended practice after the system has been operated for a sufficient period of time. In some cases, it may be advisable for the baghouse operators to consult with firms providing fabric analysis services as a troubleshooting measure. Many such groups are listed in the consultant directory sections of the <u>Journal of Air and Waste Management Association</u> and in <u>Pollution Engineering</u>.

404 PARTICULATE EMISSIONS SOURCE TESTING

Source testing is the sampling, measurement and analysis of effluent gases and/or particulate matter emitted by a stationary source to determine the type, concentration and/or quantity of specific air contaminants emitted to the atmosphere, calculated, if necessary, in terms of the applicable statute, rule or regulation, or permit condition. In other words, source testing is the process of directly measuring by some reliable and legally sanctioned method the extent of emissions from a source of pollution. This can be done in various ways, such as instrumental methods, chemical methods (wet chemistry) or physical methods (such as weighing a particulate filter catch).

The purpose of any compliance source test program is to determine the pollutant concentration or mass emission rate of a source. By measuring the pollutant concentration and the stack gas flowrate, the pollutant mass emissions can be calculated. The reliability of the test results depends largely on whether these measurements and all associated calculations are performed correctly.

Selection of the most appropriate method to be used for a specific test operation must take into consideration the chemical and physical properties of the gases to be tested. The types of analytical methods available for specific contaminants are also factors in determining the test method used.

Under the authority set forth in California Health and Safety Code section 39607(d), the Air Resources Board is required to adopt test methods to measure compliance with its nonvehicular (stationary source) emissions standards and those of the local air districts (APCD). Test methods to determine compliance can also be used for nonregulatory activities such as the determination of process emission factors or the evaluation of air pollution control equipment.

Since 1972, the staff of the ARB has developed test methods to serve the specific needs of the Board and of California's air pollution control agencies. The Board has also modified reference methods established by the U.S. Environmental Protection Agency (EPA) in Appendix A of 40 CFR, Part 60 (Standards of Performance for New Stationary Sources) and Appendix B of 40 CFR, Part 61 (National Emission Standards for Hazardous Air Pollutants).

NSPS

The EPA methods upon which ARB methods are based were promulgated for determining compliance with the EPA **New Source Performance Standards**, and are not required for determining compliance of existing sources with APCD rules and regulations.

An APCD may use its own test methods for determining compliance of existing sources with APCD rules. Both the South Coast Air Quality Management District (SCAQMD) and the Bay Area Air Quality Management District (BAAQMD) have developed and established test methods applicable to sources within their districts. If a district has not adopted its own test method, the appropriate ARB test method should be used. However, EPA has indicated that the EPA methods can be required as the referee methods in disputes over compliance that involve EPA. Therefore, regardless of the methods customarily used by an APCD, the district personnel should be familiar with the EPA methods.

ARB Method 5

ARB Method 5, which is used to determine particulate matter concentration, is based on EPA Method 5. The particulate matter concentration is determined by isokinetically aspirating a measured volume of the stack gas, catching the particulate in a heated sampling probe, in a connecting tube, in a filter, and in four impingers in series, and then dividing the weight of the particulate catch by the volume of gas. These impingers condense the water in the stack gas, condense liquid particulate matter, and catch most of the solid particulate which has passed through the filter. The first impinger catches material which would clog the nozzle of the second impinger. The second impinger catches fine particulate matter, and the third and fourth catch any remaining water or particulate matter. ARB Method 5 is presented in appendix C of this manual.

EPA Method 5

ARB Method 5 differs from **EPA Method 5** by including condensibles as an optional part of the determination of particulate matter emissions and mandating a pre-test leak check of the apparatus. A pre-test leak test is necessary to assure that the emissions are accurately determined. Inclusion of the condensible matter as a separate item is to accomodate district rules that may or may not count condensible matter as particulate. In the EPA procedure, only matter collected in the probe and the filter (known as the "front half") is counted in the particulate determination.

For many APCD rules, matter that is liquid at standard temperature must be included as particulate matter in the concentration determination. This liquid matter is assumed to pass as a gas through the filter and to then condense in the impinger water. (The weight of this liquid particulate is determined by solvent extraction using methylene chloride followed by an aqueous phase extraction.) Since many district particulate matter emission regulations include such material, ARB Method 5 assures that the method for determining particulate matter emissions will provide results consistent with applicable district emission standards.

For some APCD rules only the combined weight of the particulate matter caught on the probe and filter is used in the determination. Accordingly, it is advisable to report the weight in the impinger catch separately so that both ARB and APCD determinations, where differing, can be made. The total particulate matter catch may be itemized by weight as follows: (1) Filter Catch, (2) Probe Catch, (3) Impinger Catch, and (4) Solvent Extract.

The SCAQMD method includes the condensibles as particulate matter but specifies a slightly different arrangement of the sampling train and allows for single point sampling. The BAAQMD does not have a particulate matter test method that uses a filter external to the stack per ARB and EPA Method 5.

Cost

The **cost** of any source testing should be borne by the sources responsible for the pollution. Accordingly, Section 41512 of the California Health and Safety Code provides the authority for local districts and the ARB to assess appropriate fees to cover the cost of compliance source testing. Therefore, the cost of expanding source testing efforts necessary to conduct annual compliance tests of all sources does not have to be borne by local governments. A fee schedule could be adopted by the board of each district where source testing is appropriate.

Frequency

Most major sources should be **tested at least once a year**. However, it is difficult with the present capabilities of both local districts and the ARB to directly conduct such a testing program. One way to expand testing capabilities is to require testing by an independent testing service and charge the source for such testing. In the past there has been a reluctance to use independent testers as there was no control placed on the quality of such testing by the control agencies.

Independent Testing

Passage of legislation several years ago required the ARB to adopt procedures to allow use of **independent testing** in lieu of ARB-required testing. As a result of this legislation, the ARB adopted new sections to the California Code of Regulations. These regulations detail the ARB's authority to approve independent testers, thus providing at least some control of such testing. The Compliance Division and local districts with testing programs are working together in the ongoing process of approving such testers. These approved testing companies provide an essential part of a control agency's capability to conduct more frequent source testing.

405 COMPLIANCE ACTION

If the conditions observed during the inspection indicate that a citation is warranted, the inspector must clearly state to plant officials the grounds for such a citation. An onsite citation is justified only by clear-cut violations such as excessive opacity, or failure of the plant to report malfunctions or to maintain or provide required records for review. If baghouse performance parameter readings indicate to the inspector that the unit has problems severe enough to cause noncompliance, and noncompliance cannot be determined without a **source test**, the inspector should order a source test to be performed. If a source test is performed and the results show that the particulate emissions limit is exceeded, an NOV should be issued for each exceedance.

Source Test

The inspector may issue an NOV for any permit condition that is violated. For example, if the temperature at which a baghouse is operating does not fall within the allowable range stated on the permit for inlet and outlet temperatures, an NOV may be issued.

The inspector should go over findings with the source operator before leaving the plant. He should explain all grounds for which he is issuing an NOV.

Districts process inspection reports according to their own policies and procedures. Typically, a copy of the inspection checklist is sent to the source with a letter confirming that the inspection was made, stating any deficiencies, and requesting that they be corrected within a reasonable time. Recommendations can be given for further improvements in operation and maintenance of the baghouse, although many districts prefer that emphasis be directed toward anticipating possible problems in advance. The source should know what is expected, and the time frame it will have to accomplish the required action. Some type of **implementation plan** may be requested.

Implementation Plan

500 TROUBLESHOOTING

This chapter is written primarily for maintenance personnel at an industrial facility with a baghouse.

Appendix E

Sample troubleshooting checklists are provided in **appendix E.**

501 PERFORMANCE MONITORING

Emissions tests, also known as source tests or performance tests, determine the compliance status of an operation. These tests are useful in that measurements of parameters taken during such testing are at a known level of performance, and can serve as a benchmark or baseline condition for future comparisons with data collected during routine parameter monitoring and recordkeeping.

Baseline Conditions

The establishment of **baseline conditions** for a baghouse during a performance test provides for comparison in future evaluations of the baghouse. The baseline serves as a reference point, and the types and magnitude of shifts from baseline conditions are important in evaluating baghouse performance.

A baghouse's initial performance test can establish baseline conditions for that unit. The following key parameters should be examined during subsequent performance tests and compared against the baseline values:

1. Gas volume. If too high, it can blind the bags; if too low, it can cause dust dropout in the ducts.

2. Temperature. If too high, it can destroy the bags and/or gasketing; if too low, it might cause excursions below the dewpoint.

3. Pressure drop. If too high, this indicates potential bag blinding or high gas flow; if too low, this indicates bag failure.

4. Dust load. If too high, it may exceed the unit's capacity to convey the dust from the baghouse; if too low, it may cause excessive emissions after each cleaning cycle.

5. Particle size. Particles that are too fine can cause blinding of the bags or excessive emissions.

500 TROUBLESHOOTING

Baseline conditions should also be established for the process that the baghouse controls. Process data may include production weight, raw material and product feed characteristics, operating temperatures and pressures, combustion air settings, and cycle times (for cyclic processes).

In most of these parameters the exact effect a change will have on performance cannot be predicted. However, a qualitative evaluation can often be made when values deviate from baseline conditions. These deviation values are useful in parameter monitoring.

Troubleshooting

Parameter monitoring usually plays a key role in a **troubleshooting** plan, particularly in one that stresses preventive maintenance. Parameter monitoring also forms the basis for a recordkeeping program that places emphasis on diagnostics. Typically, daily operating data are reduced to include only the data on a few key parameters that are monitored. Acceptable ranges may be established for various parameters by use of baseline test data that require further data analysis, or perhaps some other action if the values fall outside a given range. Care must be taken not to rely on just one parameter. Other factors, both design related and operation related, must usually be considered. Typical parameters that can be monitored include opacity and pressure drop during cake buildup, and gas temperature.

Opacity Levels

Many sources use **opacity levels** as the first indicator of performance changes. In general, opacity is a good indicator and tool for this purpose. However, it is not wise to rely on opacity alone. An over-reliance on opacity can cause one to overlook problems that can affect long-term performance. For example, hopper pluggage or bridging within bags may not significantly increase opacity, but may eventually decrease the net cloth area and increase pressure drop.

Pressure Drop

Another useful parameter is the pressure differential across the fabric filter. Static **pressure drop** should be measured periodically to determine relative changes in dust cake resistance. When reviewing the operating logs, the operator should look for any increase above the previous operating levels in the lower pressure drops (after the cleaning cycle) and upper pressure drops (before the next cycle begins) across the bags. A gradual increase in resistance can indicate oil deposits, fine particulate blinding of fabric, or moisture inleakage. An increase may be tolerated if it is not severe or if a decreased ventilation performance does not result from the decreased volume of gas exhausted.

Temperature Charts

Temperature charts must be monitored to determine the potential for short-term failure caused by temperature excursions and to detect inleakage to the fabric filter housing. It is an unfortunate misconception that short term temperature excursions do not cause permanent damage, as the effects of repeated temperature exceedances on tensile strength are cumulative. A significant decrease in temperature across the fabric filter may indicate inleakage of outside air, either because of failure of gaskets around openings or the loss of the integrity of the housing.

502 RECORDKEEPING

Recordkeeping requirements vary from one plant to another, depending on the type of operation being controlled, the size of the operation, and its location. However, besides the regulatory recordkeeping obligations that a source may have, operators should consider keeping records of operating data and maintenance activities for the purposes of identifying potential problem areas and arriving at appropriate solutions.

The magnitude of the recordkeeping activity will depend upon factors such as personnel availability, size of the baghouse, and level of maintenance required. When setting up a recordkeeping program, one should give attention to both operating records and maintenance records as a means of preparing a complete operating history of the baghouse. This operating history is useful in an evaluation of future performance, maintenance trends, and operating conditions that may increase the life of the unit and minimize emissions. This approach to recordkeeping makes the effort both worthwhile and cost-effective.

Useful Parameters

For most baghouses, the two most **useful operating parameters** are the opacity and the pressure drop across the filter material. In some applications, temperature data will be important for evaluation of the impact of high temperature excursions of condensation. The frequency for collection of these data will depend on several factors, but as a general rule, these data should be checked once a day. Figure 502.1 shows a circular opacity chart.

Continuous strip-chart recorders for opacity, pressure drop, and temperature can be very useful for indicating daily trends. The use of continuous strip-chart recorders is often limited to larger sources, however. Opacity monitors also tend to be used only in certain applications and at large industrial sources. Most small sources that use fabric filters have no opacity monitors. All sources, however, have means of monitoring temperature, and when baghouses are applied to high-temperature sources or in situations where temperature problems may occur, the inlet gas temperature should be monitored continuously.

In the absence of continuous monitors/recorders, visible emission characteristics and onsite instrumentation must be observed periodically and the results evaluated. Opacity observations are very useful at most applications because opacity plumes at a properly operated and maintained baghouse are generally very low, except when a condensible plume is present. A relatively continuous elevated

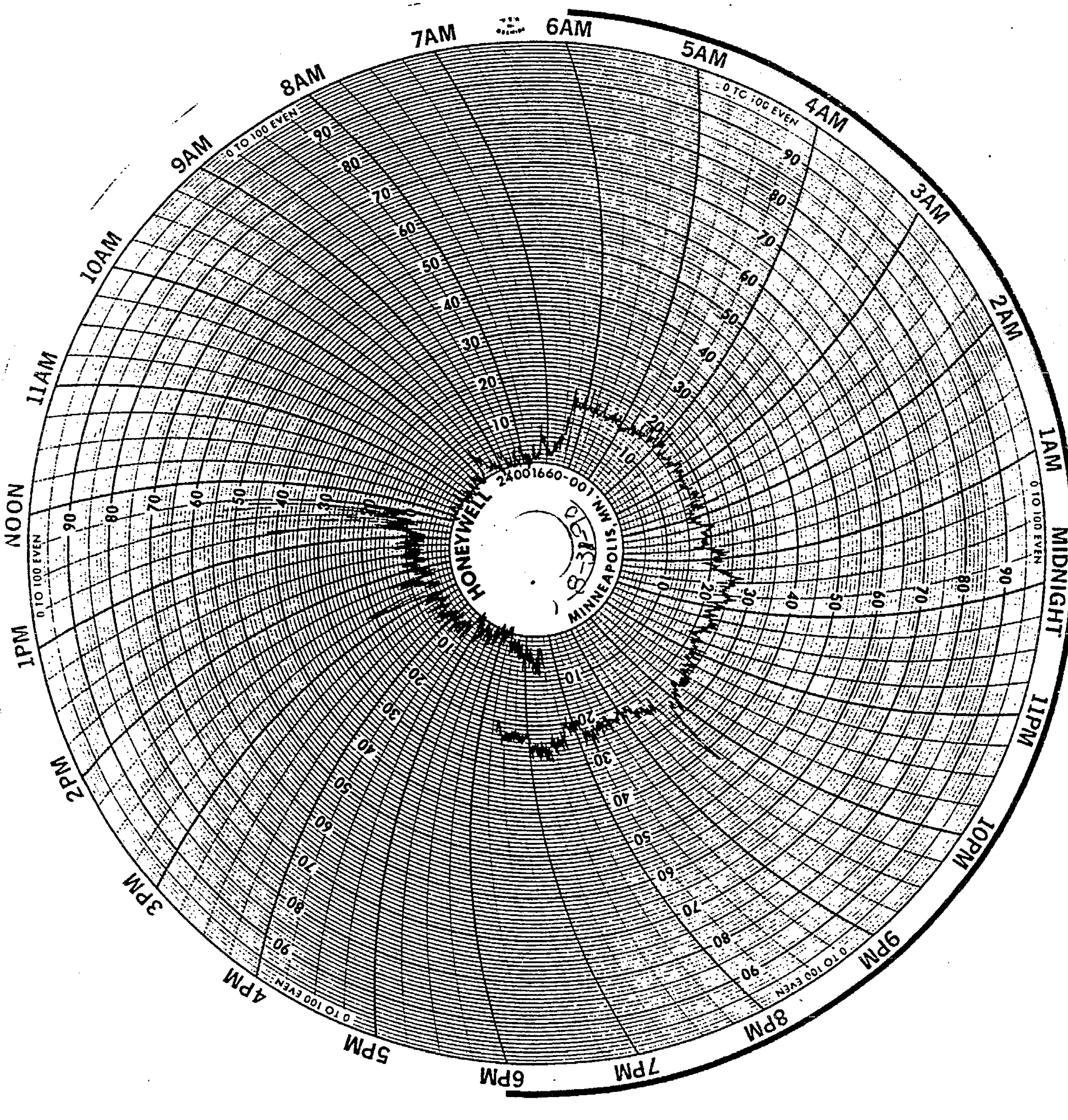


Figure 502.1 Circular Opacity Chart

Pinhole Leaks

opacity level can be indicative of the presence of major leaks and tears in the filter bags. **Pinhole leaks** are also usually discernible by an increase in opacity after cleaning of the bags. These kinds of plume characteristics are usually discovered by continuous observation of the plume rather than once every 15 seconds. In general, continuous observation of the plume to note any changes is better suited for evaluating maintenance requirements, as problems in certain rows or modules can be identified by this method.

General Operating Range

The pressure drop across the baghouse gives an indication of the resistance to gas flow and cleaning effectiveness. The pressure drop usually varies with the square of the gas volume flow through the fabric, but it will also vary with the thickness of the dust cake and the amount of material permanently retained by the fabric filter. This value will depend on various factors. The pressure drop of a baghouse, however, generally falls within a typical range, and it is this range that is important. The recorded value should fall within the **general operating range** for the unit. Any changes in the pressure drop, whether gradual or sudden, may indicate the need for maintenance. If the cleaning cycle is initiated by a specified pressure drop, however, the pressure drop will not change, but the time between cleaning cycles will be shortened.

When a large number of baghouses must be evaluated, forms may be printed that include the typical or baseline values so that an immediate comparison can be made. For large, multicompartmented filter systems, recording the pressure drop across individual modules may not be necessary because pressure drop tends to equalize across all the modules.

For those units on which operating temperature is of particular concern, the use of continuous strip-chart monitors is highly recommended. Sometimes bag damage is not evident until days or weeks after a temperature-related incident. This can be troublesome to maintenance personnel because failure to detect the cause of deteriorating bags can result in unusually high maintenance costs. Although both inlet and outlet monitors are recommended, measurement of only the inlet gas temperature is usually sufficient. Temperature readings recorded during the acquisition of other data (opacity, pressure drop, production rate, etc.) are usually of little use by themselves, since they are not continuous.

Maintenance records are also useful in evaluating fabric filter performance. A record of bag failures and/or bag replacement (figure 502.2) can be especially helpful. In a typical application with newly installed bags, random bag failures

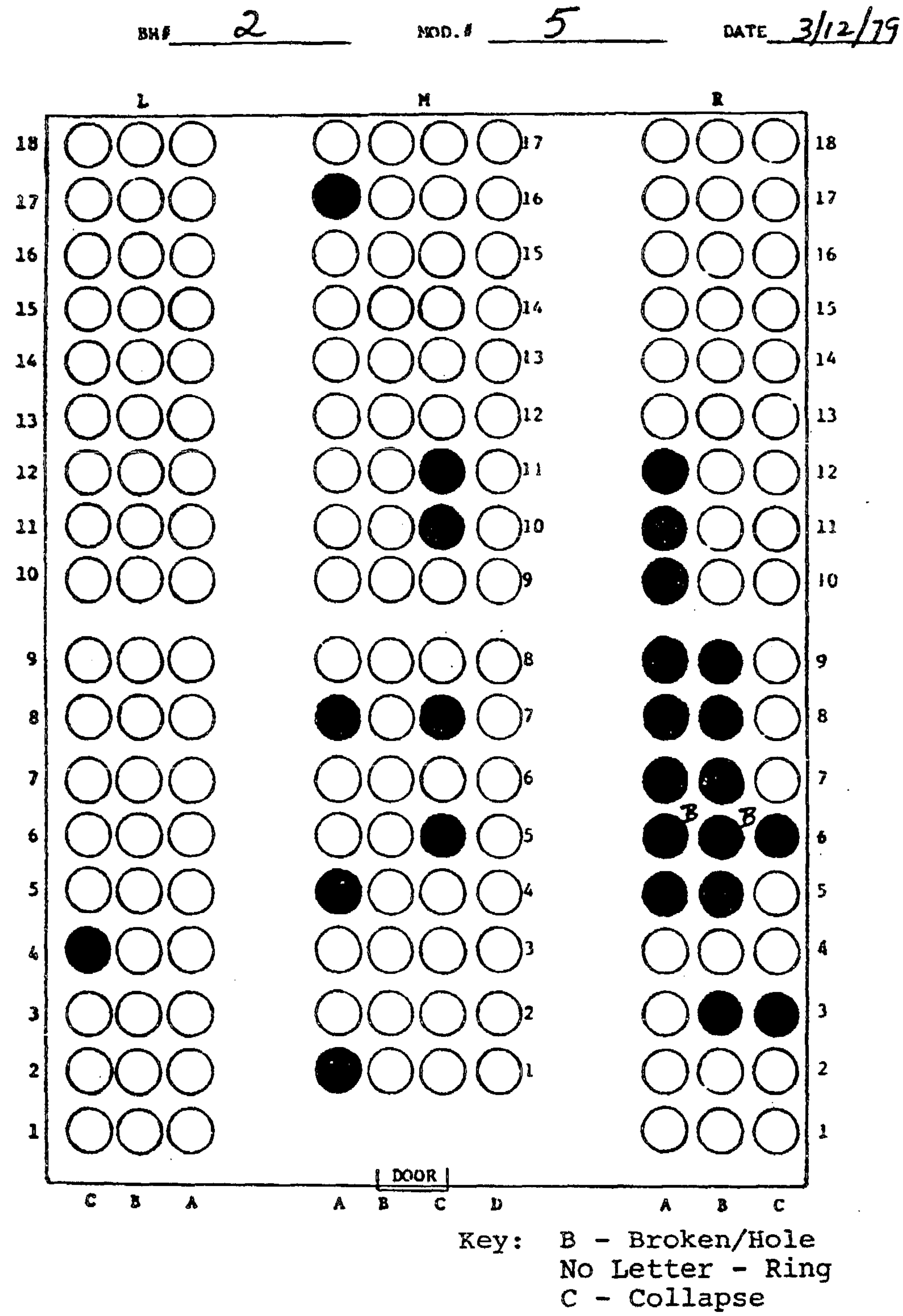


Figure 502.2 Typical Bag Replacement Chart [15]

shortly after startup is not uncommon. These are usually caused by an occasional defective bag and by installation problems. After these failures occur during the shakedown period, bag replacement requirements are expected to be minimal until the bags near the end of their useful lives. Records of bag replacement location, however, may reveal the presence of **failure patterns** resulting from design or operating practices. The existence of such a pattern may suggest a possible cause and solution that will improve performance and reduce maintenance costs in the long run.

Bag Failure Pattern

Another characteristic that bears examination is the physical property of the dust and any associated changes that may have occurred. Although site-specific factors control the characteristics of the dust to be controlled, two general characteristics that can influence fabric filter performance are particle size distribution and the adhesive **characteristics of dusts**. Changes in particle size distribution may increase abrasive wear if the particles increase in size. On the other hand, a shift to a smaller particle size range may increase penetration (bleed-through) and blinding. Changes in process operating characteristics can sometimes cause significant shifts in particle size. Changes in adhesive characteristics can also result from variations in process operation conditions (e.g., some combustion sources can produce "sticky" carbon particles if combustion characteristics are poor) or fluctuations in temperature that produce dewpoint problems. Where such changes are possible, routine monitoring of dust characteristics may be prudent to prevent excessive or unexpected maintenance problems.

Dust Properties

503 PROBLEM DIAGNOSIS

The two major categories of operation and maintenance problems are: 1) problems that can affect fabric filters regardless of type, and 2) problems that are characteristic of a particular cleaning system design. The first category includes fabric failure, dust discharge problems, corrosion, poor or improper maintenance considerations, and other problems that are common to nearly all fabric filter types. The discussion of problems in the second category is presented by system design:— shaker, reverse-air, or pulse-jet. Some hybrid systems will not conform to these criteria, and site-specific design factors must be considered. Most failure modes, however, are addressed here.

The factors that contribute to fabric failures include improper installation, high temperatures, condensation, chemical degradation, high air-to-cloth (A/C) ratio, high pressure drop, and bag abrasion. Each of these is discussed separately.

503.1 INSTALLATION

Training

The first step in achieving the expected performance from the fabric filter is proper installation of the bags in accordance with the guidelines provided by the bag manufacturer and the equipment vendor. Because these guidelines are not always available to maintenance personnel, training of maintenance personnel in proper installation procedures is very important. Reasons for lack of **training** vary, but generally they result from lack of vendor-supplied training and maintenance manuals, and turnover in maintenance personnel. The latter creates a situation that necessitates almost continual training. Common problems resulting from improper installation of the bags include leaks around seals, improper bag tensioning, and damage to the bags during handling.

Failure of a few new bags is to be expected in a new or rebagged fabric filter, even during normal operating conditions, as a result of occasional manufacturing defects and improper handling during installation. After these few initial failures, however, if the system is properly designed and operated, the occurrence of such failures should be at a very low level until near the end of the bag life, when failures are likely to start increasing. If installed improperly, however, bags may continue to fail long after the initial installation and long before they approach the end of what should be their normal life.

500 TROUBLESHOOTING

To some extent, the design of the fabric filter can influence the extent of bag damage during installation. Systems that provide good access and are designed with maintenance considerations in mind reduce the likelihood of bag damage. The poor access design of a reverse-air fabric filter is not conducive to proper installation and maintenance (see figure 503.1). Examples of designs that facilitate bag replacement or installation are in pulse-jet systems with top-loading bags or reverse-air or shaker systems with a maximum "**bag reach**" of two or three bags. These designs allow maintenance personnel to disturb only a minimal number of "good" bags. Obviously, little is gained if the replacement of one or two bags results in the damage and life-shortening of several others.

Bag Reach

In reverse-air and shaker-type fabric filter installations, damage often occurs when the bags are being hung. Access to the bag support and tensioning mechanisms may be difficult and cumbersome, and personnel may prefer to hang all of the bags at once and then attach them to the tube sheet after all of them are suspended. The tendency, however, is to **tie the bags** out of the way as they are hung in the enclosure. Some fabric types can withstand this treatment with few problems, whereas others (most notably fiberglass) cannot. If the fabrics have poor abrasion resistance, tying the bags can cause leaks to occur wherever a crease is formed. Efforts should be made to tension these bags properly as they are installed, as this adjustment is sometimes difficult after all the bags have been hung. Care should also be taken to avoid stepping on the bags as they are taken out of their cartons or when they are laid on the floor prior to installation.

Tying Bags

Fabric filters with pulse jet cleaning systems (or any other design where filtration occurs on the outside and a cage is used for bag support) generally have shorter bags, which are a little more manageable. Most of the damage during installation of these bags occurs when they are placed on the cages. These bags generally fit snugly, and damage may result from improperly sized bags or sharp edges on the cages. When a number of bags are being installed, the bags are generally placed on the cages and stacked prior to their installation. This can result in bag damage unless special care is taken. These bags can also be damaged if they must be slid through a tube sheet and the fit is too tight. The “nip” or amount of the bag that can be drawn away from the cage for a correct fit is about 1/4 inch.

In summary, failure to take appropriate precautions to safeguard the bags during the installation process may result in excessive maintenance due to bag failure or reduced bag life.

CORRECT AND INCORRECT BAG INSTALLATION

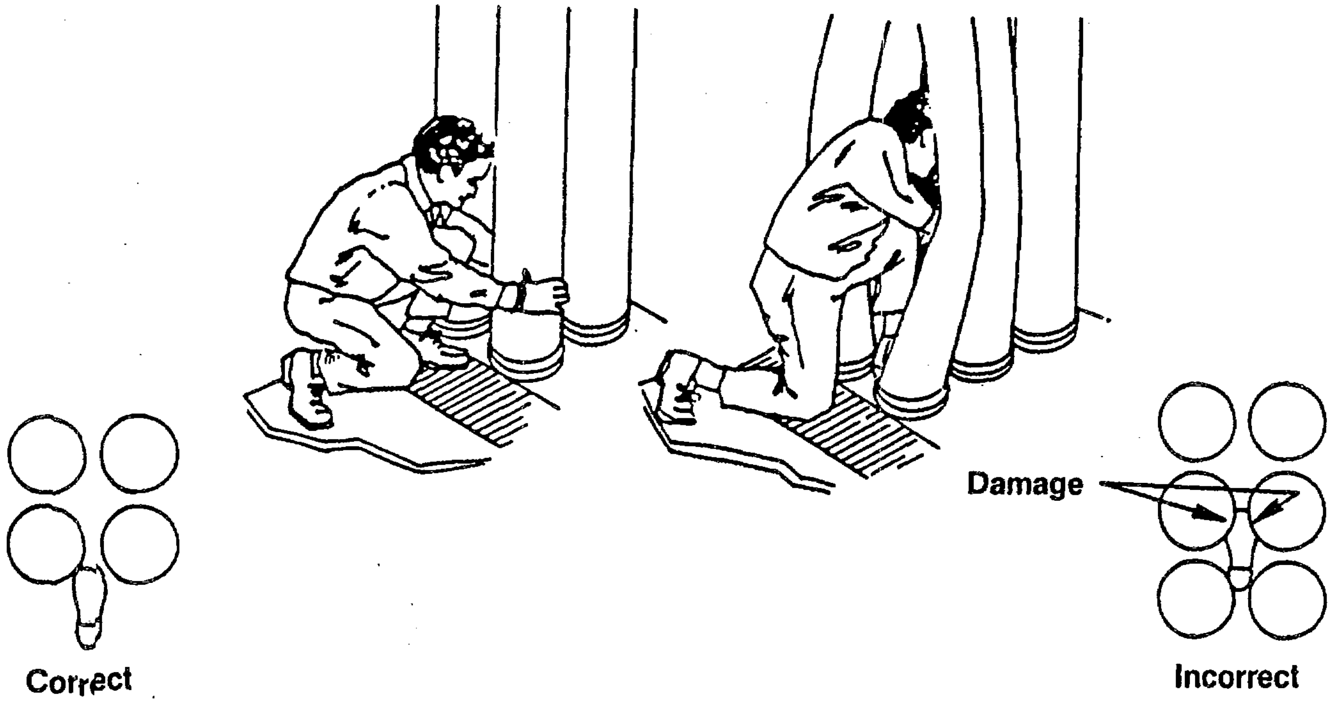


Figure 503.1 Methods of Installing Bags In a Reverse Baghouse 16

503.2 HIGH TEMPERATURE

High temperatures are not a consideration with many fabric filter applications; however, in those that operate above 150 °F, the effects of temperature on the fabric must be considered. High temperature breaks the polymer chains in most commercially available fabrics, which causes loss of strength and reduces bag life. The effects are different on high-temperature fiberglass. The high temperatures attack the finish that has been applied to the fiberglass to reduce fiber-to-fiber abrasion, and when this finish is destroyed, the bag can abrade itself and self-destruct. Sometimes it takes several days or weeks before these bags begin to fail. The fabric type is chosen on the basis of expected temperature ranges, and care must be taken to provide an adequate margin for error. Temperature monitors and alarms are often used to avoid high temperature excursions. Excursions above the recommended temperature limit generally shorten bag life considerably; however; the closer the actual operating temperature is to the fabric's temperature limit, the shorter the bag life will be.

503.3 CONDENSATION

Blinding

Power Requirement

Condensation of moisture and/or acid gases is generally associated with reduced temperatures within the fabric filter. Condensation of moisture or acid mist on the bags tends to alter the adhesion characteristics of the dust cake on and within the fabric structure, and "mudding" or **blinding** of the bags may occur because the cleaning system cannot remove this dust. This usually increases the pressure drop, and **more fan energy is required** to overcome the added resistance through the dust cake.

Such conditions may occur near the walls of the unit when warm, moist, or acidic gases pass through a cool or cold fabric filter that has not been preheated. (For example, it is often advisable to preheat the fabric filter unit at an asphalt plant prior to introducing wet aggregate to the dryer.) Condensation may also occur if moist gases are not purged from the unit before it is shut down. When the temperature is allowed to cool below the dewpoint at the end of a production run, moist or acidic gases should be purged to prevent condensation on the walls and the bags within the fabric filter.

503.4 CHEMICAL DEGRADATION

Chemical resistance refers to the fabric's ability to withstand acidic or alkaline conditions. Fabrics are rated according to their chemical resistance, but care must be exercised with regard to these classifications because certain fabrics are more susceptible to some chemical species than to others. Fiberglass bags generally are rated as having good acidic resistance; however, the use of fiberglass bags in atmospheres with appreciable quantities of hydrogen fluoride would not be advisable. Nomex® is generally rated as having fair acid resistance. It is also generally known for its good moisture and SO_2 resistance; when both water and SO_2 are present, however, sulfurous and sulfuric acid mist is formed, the aramid structure of Nomex is attacked, and the fabric loses its strength. Individually, water vapor or SO_2 do not present a problem to Nomex, but in combination they can result in costly bag failure.

503.5 HIGH A/C RATIO

High A/C ratio generally results from an increase in gas volume moving through the system or the installation of an undersized system. The cleaning system type generally controls the range of acceptable A/C ratios; the lower-energy cleaning systems (reverse-air and shaker) use lower A/C ratios. Other factors, such as dust loading and particle size distribution, also influence the design A/C ratio. In general, the higher the A/C ratio, the higher the operating **pressure drop**. Excessively high A/C ratios, however, can result in very high pressure drops, and **bag abrasion** is increased because the particles impact the bags at higher face velocities. Bag blinding or an increase in the residual dust loading after cleaning also may occur because both the increased pressure drop across the bag and the increased velocity allow dust to penetrate into the fabric, where the cleaning system is unable to remove it. This will cause a gradual increase in pressure drop across the bags. The net result is generally an increase in **energy requirements** to maintain gas flow, and a decrease in bag life.

Pressure Drop

Bag Abrasion

Power Requirements

503.6 HIGH PRESSURE DROP

As noted previously, high pressure drop can be a symptom of high A/C ratios. It can also occur when the cleaning system fails or when little or no cleaning energy is supplied to remove the dust cake from the bags. The greater thickness of the dust cake increases the resistance to gas flow, which in turn is reflected as an increase in pressure drop across the bags. High pressure drop also can result from bag blinding or condensation in the bags. Although it is usually a symptom of some other problem, high pressure drop itself may cause other problems. First, the greater resistance to flow tends to decrease gas flow through the fabric filter and can lead to fugitive emissions from the emission source. An increase in expended energy is required to maintain gas flow. Second, the greater differential pressure between the dirty and clean side of the fabric provides a larger amount of energy to draw particulate matter into the weave of the bag, which can lead to more abrasion damage within the bag and to shortened baglife. Lastly, a very high pressure drop (10 to 14 in. H_2O) may cause the bag to be unable to withstand the pressure differential and to tear at points where the bag's strength has been reduced. In most fabric filters, only a few affected bags can lower the pressure drop and allow significant quantities of gas to pass through the fabric untreated.

Although high pressure drop is usually a symptom of other problems and should be treated as such, it should not be ignored. Even if the related problem does not shut the fabric filter down, the high pressure drop will lead to higher energy costs, reduced bag life, and increased maintenance costs.

503.7 BAG ABRASION

Bag abrasion may be caused by contact between a bag and another surface (e.g., another bag or the walls of the fabric filter) or by the impact of higher-than-average gas volumes and particulate matter loading on the bags. Bag-to-bag contact can be a problem in nearly every type of fabric filter if the bags are not installed properly. Such contact may eventually wear a hole in the bag, and the resulting jet of gas flow through the hole will gradually enlarge it. On bags that collect dust on the inside, a hole may cause a high-velocity jet to impinge upon an adjacent bag and also eventually wear a hole in it.

Diffusers

Blast plates or **diffusers** (and sometimes precleaning devices) are recommended for many fabric filters. The purpose of these devices is to reduce the quantity of large particles that strike the bags and, along with long thimbles on shaker and reverse-air systems, to help minimize the wear on the bottom of the bag. Because of their size and weight, these large particles have great inertia, which allows the particles to strike the bag at an angle and eventually damage the bags.

These particles have a tendency to stratify in the inlet of the fabric filter because their inertia reduces their ability to follow gas streamlines. It is not unusual to find abrasion problems in the bags on the side opposite the inlet. On most bags the greatest abrasion occurs within 18 to 24 inches from the bottom of the bag. Diffusers tend to help reduce the problem, and the diffuser should be checked periodically for wear.

Holes

Holes in the bags usually cause an increase in opacity, if small particles are present, and they also may cause a reduction in pressure drop. Pinholes are usually covered easily by the dust cake; thus, opacity increases after the bag is cleaned. This increase in opacity is relatively short, however, and diminishes as the pinhole is covered again. Tears or holes in the bags may or may not be covered by the dust cake, depending on their size and the pressure drop across the bags. The opacity generally will not decrease quickly or substantially, however, because the hole(s) may allow a significant quantity of material to pass through the system. Thus, opacity can be an indicator of the relative magnitude of any holes formed by abrasion.

503.8 DUST DISCHARGE FAILURES

Fugitive Emissions

Hopper pluggage can cause serious problems in a fabric filter. Regardless of the reason (cooling of the dust, inleakage, failure of the discharge system operation, or simply using the hoppers for storage), failure to remove the dust from the hopper usually results in having to open up the hoppers to clean them out. This can result in **fugitive emissions**. The fugitive emissions generated by a single cleaning out of the hoppers may be greater than the emissions emanating from the fabric filter outlet for an entire year. Therefore, minimizing the occurrences of hopper pluggage by emptying hoppers continuously or frequently is very important.

Hopper Pluggage

Many dusts flow less easily when they are cold than when they are warm. Thus, insulation, hopper heaters, and continuous dust removal may be necessary to minimize the hopper pluggage problems. The effects of **hopper pluggage** are not always immediately obvious. As the dust builds up, dust resuspension may increase, as most fabric filter inlets enter through the hopper. This increase in resuspended material will increase the particulate loading on the bags, and it also may cause an increase in the pressure drop across the bags. When the dust buildup in the hoppers reaches a certain height, some bags may be partially or completely blocked from the gas flow, which increases the gas flow (A/C ratio) for the remaining bags and further increases the pressure drop. Eventually, all gas flow from the hopper inlet may be blocked. Dust buildup in and around the bags can be a problem, particularly as condensation occurs when the dust is cooled. This can lead to a condition similar to bag blinding.

503.9 SHAKER CLEANING SYSTEM FAILURES

Because gas flow from the fabric filter must be cut off before the shaker cleaning system can be operated, shaker-type fabric filters are either modularized or they are applied to intermittently operating sources where gas flow can be stopped so the shaking action can be effective. Several problems are characteristic of shaker-type fabric filters.

Shaker motors can be installed inside or outside of the fabric filter housing depending on the temperature and corrosive conditions in the gas stream. These small motors (most are less than 5 horsepower) are usually installed outside the housing and are wired into a control circuit that may be manually or automatically activated. Operation of these motors, however, can be difficult to evaluate. Failure of the shaker motor may (and in many cases does) lead to excessive dust cake buildup on the bags and an increase in pressure drop. In some applications, when the gas flow is stopped by closing the dampers, the dust will slide off the bag. In most applications, however, the shaker system is needed for adequate removal of the dust and maintenance of a reasonable pressure drop.

The shaker linkages must be maintained in a manner that allows the energy provided by the shaker motor to be distributed through the shaking system to the bags. Because these systems are mechanical, periodic lubrication, checking for wear or loose parts, and replacement of broken parts are required to maintain their cleaning effectiveness. The only way to evaluate this system is to watch it in operation to ascertain that all the bags are being cleaned at approximately the same intensity. Watching the system operate may reveal that certain modules or certain shaker bars are not being moved through the correct amplitude. These sections have higher resistance to flow, and the gas is forced to flow through the bags having less resistance to equalize the pressure drop. Although the overall pressure drop may increase somewhat, abrasion and blinding damage may occur in the bags being cleaned more effectively by the shaker system.

The third problem in fabric filters with shaker cleaning systems concerns bag tension (figure 503.2). Bag tension changes with the age of the bag and with the

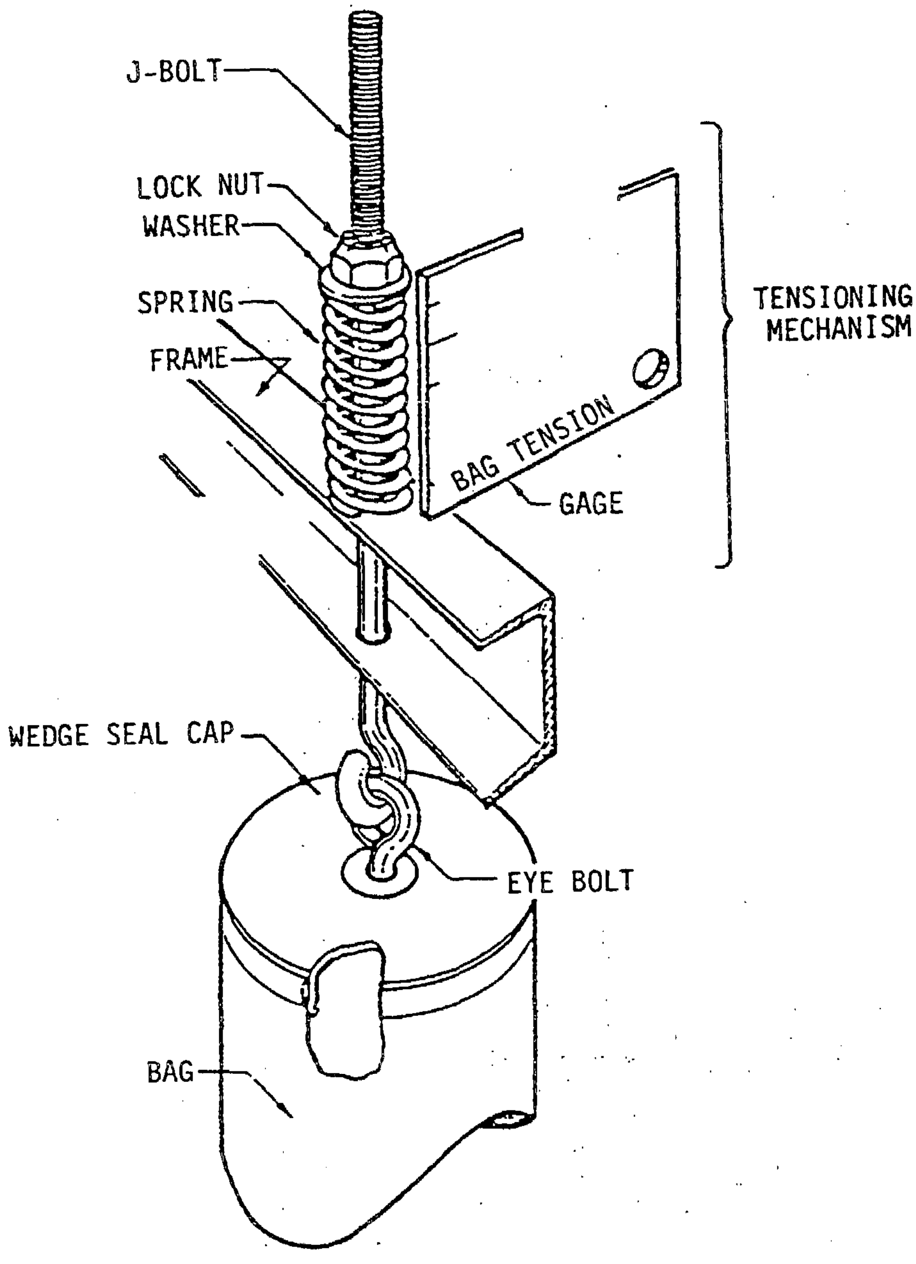


Figure 503.2 Typical Spring Bag Tensioning Arrangement [17]

Bag Tension

amount of material collected on the dust layer, and it is usually expressed in the number of pounds of force applied to the top of the bag. Thus, **bag tensions** are usually adjusted by some arrangement at the top of the bag. Bags that are too tight may not transfer the shaker energy effectively and may be damaged during shaking. Bags that are too loose may sag on the tubesheet, and bag abrasion may result from the bag being placed in the gas stream or being contacted by the thimble or other bags. Loose bags also may not use the cleaning energy effectively and may block the flow of dust out of the bags if they sag, fold, or close off above the tubesheet. Proper tension allows the dust to flow out of the bag without sagging problems or problems in the transfer of shaker energy.

Hanging Mechanism

Problems can occur in the bag **hanging mechanism** if bag tensioning is not proper. Some systems use chains or threaded bolts that attach the shaker bar to the top (metal cap) of the bag. In other cases, the bags have a tongue that is threaded through a clip, and friction is used to keep the bags on their hangers. Maintenance personnel must properly install the bags to ensure that they remain attached at the top and that they won't fall down or lie on the tubesheet. When fabric filters are used to control dense dusts (e.g., in the metals industries), the bags sometimes fall because they were installed improperly or because bag tension and/or cleaning efficiency were inadequate to remove the dust from the bags. When bags become heavily ladened with dust they will pull away from the attachment mechanism or cause this mechanism to break. Because the bags that lie on the fabric filter floor are essentially out of service, the actual A/C ratio, the pressure drop, bag wear, and maintenance costs will increase.

503.10 REVERSE AIR CLEANING SYSTEMS

Intermittent Cleaning

Like the shaker cleaning system, the reverse-air system is a low-energy system that cannot function properly if gas flow is present in the module or area being cleaned. The damper systems for fabric filters with **this cleaning mechanism** tend to be more complex than those for the shaker system because a reverse flow of gas is used to collapse the bag, to break and release the dust cake, and to allow it to be collected and removed from the fabric filter. Failures in this type of filter system are most often related to the improper functioning of the cleaning system.

Several types of reverse air cleaning system designs are available. Some use a separate reverse air fan, and others do not. Whatever the particular design, the gas flow must be stopped in the module so that cleaning may take place. This requires a positive seal on the reverse air isolating damper (a poppet damper is often used). Without proper sealing the bags may not collapse properly and the cleaning action may be ineffective. Unlike the other cleaning systems, relatively little energy is available to clean the fabric, as the reverse flow of gas through the bags is usually small compared with normal, on-line gas flow. Over a period of time, the overall pressure drop will gradually increase because of buildup on the bags.

Damper Failure

Failure of the isolation dampers is usually easily detected, as the actuators are generally pneumatically or hydraulically operated and the movement of the piston is visible. Too little movement of the piston usually indicates that the damper is not sealing properly. Symptoms of problems are similar to those for the reverse-air supply dampers. In some situations, the **failure of the damper** system can be detected by a missing spike and subsequent decrease in pressure drop after the affected module comes off line for cleaning. Moisture and oil in the compressed-air supply lines can cause blockage during freezing weather and result in the failure of these pnuematically operated systems. Damper operation failures, however, usually result from failures of the controlling timers or pressure drop sensors that are used to activate the cleaning cycle at certain intervals or at certain pressure-drop thresholds.

Buildup of materials around the dampers or deformation of the dampers or their seals can cause problems with proper isolation of a compartment for cleaning. Symptoms of this problem are similar to those for a malfunctioning damper system, and they may register on the continuous pressure drop recorder. The major difference is that the damper would appear to be functioning. Confirmation of poor damper sealing is only possible by internal examination of the equipment, and even internal inspection of the damper system may be inconclusive because the system must be cooled sufficiently for safe entry. An internal inspection, however, may indicate the presence of light leaks, warped dampers and seals, or buildup or wear of the dampers caused by material passing through the fabric filter. The damper operation and seal should be checked periodically as part of a preventive maintenance program.

Bag Tension

Proper **bag tension** is essential to bag cleaning. Just as it was important for the bags to be properly tensioned for the shaking action to be effectively transmitted to the bag, attention to bag tension is necessary to obtain the proper collapse and flexing of the dust cake for its removal from the bags. Bags that are tight may not collapse enough to allow effective flexing of the dust cake. Too much

Abrasion

tension can also damage the fabric. On the other hand, insufficient tension of the bags may allow the bags to collapse to the point where the bag is closed down during the reverse-air cleaning cycle (even when anticollapse rings are used). Loose bags also may suffer **abrasion** due to the bag being sucked down into the thimble. It is recommended that thimbles be rounded and free of sharp edges to prevent tears if this should occur.

Proper bag tension is a function of attention to detail during the initial installation. Bags must be hung properly, without damage, if the proper life expectancy is to be achieved. Bag tension will vary with the age of the bag and also within any given cleaning cycle as material builds up on the bags. Poor bag tension can increase bag wear, cause high pressure drop, and shorten bag life.

Corrosion

Corrosion also can be a problem in this type of fabric filter. In some applications, most notably where acid dewpoint conditions have not been adequately considered, corrosion of the metal anticollapse rings results in abrasion and wear of the bag at the site of bag ring contact. Sometimes fuels or process parameters can be modified to reduce potential corrosion. Special alloy metals or coatings also can be used to minimize or eliminate corrosion problems.

503.11 PULSE JET CLEANING SYSTEMS

Energy Requirements

Pulse jet fabric filters are widely used because of their smaller size and because their higher available cleaning energy allows for higher A/C ratios. Despite the attractiveness of their lower initial costs, however, these bags have their limitations and potential problems because of the higher **energy required** to operate these systems.

Abrasion

The higher A/C ratios on this fabric filter type increase the potential for fabric **abrasion**. Therefore, greater efforts should be made to minimize other, often-overlooked, abrasion-related failures.

Typically, the bags in a pulse jet fabric filter are suspended from a tubesheet and supported by a cage. This single-point method of attachment allows the bag to move around during normal operation. One source of bag abrasion is bag-to-bag contact due to improper installation, poor alignment of the bag/cage assemblies with the tubesheet, or bent/warped cages. The rubbing together of the bags (usually at the bottom) can wear a hole in one or more of the bags.

Bag Misalignment

The **misalignment of bag/cage** assemblies can also cause other problems. In some designs, the misalignment of the cage will prevent proper sealing of the bag with the tubesheet. This may allow some of the dust to bypass the filter area, which decreases performance but probably causes little or no change in pressure drop. Particularly abrasive dust has been known to wear the bags and the tubesheet so severely at the point of the leak that achieving an adequate seal may be impossible without replacing the tubesheet.

Another abrasion-related problem concerns the condition of any baffle or blast plate that may be installed at the inlet of the fabric filter. The purpose of this device is to "knock down" the heavier particles and to distribute flow such that the larger particles do not strike the bottom of the bags opposite the inlet. Not all designs are equipped with a blast plate, which should bring the gas flow below the bottom of the bags. When failure of the bags occurs within about 18 inches of the bottom on the side opposite of the inlet, the presence and integrity of the blast plate or diffuser plate should be checked. Although other problems with the cleaning system can lead to increased bag wear and poor performance through higher pressure drop, these problems tend to be more indirect in nature.

Continuous Cleaning

The design and operation of the pulse jet system generally call for **on-line cleaning**, which requires the availability of considerably more cleaning energy to remove the dust from the bags (in addition to the higher A/C ratios normally encountered with this design). Failure to provide this energy will generally show up quite readily as an increase in pressure drop because a relatively small cloth area is handling a large gas flow. Several components can contribute to such a problem.

The compressed-air supply must be able to provide a pressure of between 90 and 120 psig to clean the bags effectively. Compressed-air requirements for short bags (6 to 8 ft) may be lower (say 60 to 90 psig); whereas for 14 ft bags, pressures of 120 to 140 psig may be necessary for adequate cleaning. The pressure must be high enough to clean the entire length of the bags during the pulse, but not so high that it damages the upper portion of the bag. Insufficient cleaning of the bag may gradually increase pressure drop and reduce the useful bag life. Too low compressed-air pressure, which is usually more common than excessive pressure, may be caused by wear of the compressor rings, leakage of diaphragms, or excessive draining of the reserve of the compressors by other equipment tied to a common supply line.

Diaphragm

Leakage around a **diaphragm**, which can usually be detected audibly by the absence of the resounding "thud" that typically characterizes proper operation of the pulse-jet system, affects the cleaning effectiveness for all the bags. Although it may take several hours or several days, the pressure drop usually will increase eventually if the leak is severe enough.

Solenoid

Failure of the **solenoid(s)** or the timer circuit may cause one or more rows not to be cleaned. Effects on fabric filter performance may range from indiscernible to complete cutoff of gas flow, depending upon the percentage area of the bags affected and the dust characteristics. Both mechanical and electronic timers are still in use, and both have certain advantages and disadvantages. Both types must be kept in a dust-free, dry environment and relatively free from the shocks and jolts that can accompany normal operations. Solenoid failures affect the row that has experienced the failure, whereas timer failures tend to affect most, if not all, of the fabric filter system.

Loose Pipe

When the timer activates the solenoid that opens the diaphragm at the end of the pulse pipe, the force of the compressed air entering the pulse pipe and discharging into the bags places considerable stress on the pulse pipe. In some instances, the force is sufficient to break the attachment at the other end of the pipe (usually a bolt and nut), which allows the pipe to bounce around inside the fabric filter when the row is cleaned. Several problems may result. First, the pulse pipe may not be properly aligned to provide effective cleaning to that row. Second, the alignment may be such that the pipe openings are aimed directly at the bags and can blow holes in them. Lastly, the **loose pipe** may damage the tubesheet or even the fabric filter enclosure, which would necessitate additional repairs. The sound of a loose pulse pipe is usually unmistakable, as it moves around whenever the pulse-jet compressed-air is fired into that pipe.

Compressed Air Quality

Although all of these problems are relatively common in most pulse-jet systems and may produce bag abrasion or shorten bag life, the one problem that seems to recur with greatest frequency is the presence of water and/or oil in the pulse-jet compressed-air supply. **Compressed-air** systems can be equipped with small water and oil traps that work well if the compressor is maintained and the humidity is not excessive. Even these systems, however, must be drained periodically to be effective. Water and/or oil that are blown into the bags during cleaning tend to absorb through the bag and cause bag blinding as the dust cake becomes wet. The result is usually excessively high pressure drop through blinded bags, which must be thrown away. The oil usually comes from leakage around worn rings and seals in the compressor and the moisture comes from the atmosphere. The rate at which the bags are affected depends on how much water and oil enter the system.

504 CORRECTIVE ACTIONS

Fabric filters generally have a potentially high collection efficiency, but they must be maintained properly to achieve acceptable long-term performance. This includes preventive maintenance and the correct diagnosis and solution to problems as they occur. Some of the corrective actions are obvious. Even so, the bulk of the maintenance effort seems to be aimed at correcting the symptoms of problems rather than finding the cause and correcting it to avoid recurrence.

Find Causes of Problems

For example, if a set of bags are destroyed by burning, they obviously must be replaced. That solves the immediate problem of high emission rates, but it doesn't answer the following questions. What caused the bag damage? Is there a high temperature alarm and recorder in the system? Does it work? Could this have been prevented, and can it be prevented in the future? Trying to **find the cause of a problem** and to correct that cause involves a different approach and attitude than simply treating the symptoms. This difference should be recognized by both plant and regulatory personnel. This section stresses how this difference can effect long-term compliance expectations and in some cases, control costs.

504.1 INSTALLATION

Failure to install filter bags properly almost certainly guarantees future problems with the bags. For example, on pulse-jet fabric filters aligning and sealing the bag at the tubesheet are somewhat difficult tasks. In some applications (e.g. cement clinkers) the dust is very abrasive and will eventually wear away the tubesheet at points where the bag is not sealed properly. This can necessitate replacement of the tubesheet if the wear is so significant that the bags can no longer be sealed, even with extra effort and attention on the part of maintenance personnel. When this occurs, the lost production and equipment replacement costs are substantial, a problem that could have been avoided had the bags been installed properly at the outset.

A little more attention to detail and proper installation can often make the difference between good and poor performance and acceptable and unacceptable bag life.

504.2 HIGH TEMPERATURE

The effects of high temperature conditions can range from a few holes in the bags caused by sparks to complete destruction of all the bags resulting from generally high temperatures within the baghouse. Although damage from high temperatures is usually limited to sources operating at elevated temperatures, it cannot be ruled out for sources where spark carryover into the fabric filter is a potential problem. For example, in the furniture and woodworking industry, sanders and abrasive planers have the potential to throw a spark into the gas stream that may then be carried to the fabric filter. The ensuing fire or explosion will destroy the bags just as surely as if the air temperature had been raised over the bag temperature limitation. The use of temperature monitors is usually recommended at sources that operate at elevated temperatures, and plant personnel generally install alarms and perhaps an emergency bypass system to protect the system from temperature excursions. A temperature monitor would be useless in the example cited above, however, because the temperature sensor would not react quickly enough to take action to avoid the situation. **Spark arrestors** have been used with some success where sparks (not high gas temperature) have proven to be a problem.

Spark Arrestors

When high temperature damage to the bags does occur, the cause of the temperature excursion (e.g., operator error, process upset and nature of upset) should be determined and action taken to prevent the recurrence of the problem. This might entail the installation of temperature recorders where none existed previously, the addition of temperature-conditioning systems or an emergency bypass, education of operators to avoid certain conditions, or combinations of conditions that may lead to high temperature excursions. Proper identification and correction of the cause of high temperatures usually prove to be much less expensive than periodic replacement of the bags.

504.3 CONDENSATION

The condensation problem can generally be corrected by increasing operating temperature, decreasing moisture and/or acid gas levels entering the fabric filter, or by insulating the fabric filter more effectively (if insulation already exists). Removal of the gases prior to shutdown and **preheating** the fabric filter before startup (usual purge and preheat times range from 5 to 20 minutes) also may minimize the potential for condensation within the fabric filter. All of these points could be considered as changes in operating practice.

Preheating

When a fabric filter already has a bag blinding problem as a result of condensation, little can be done but to change the bags and try to avoid a recurrence of the conditions that caused the problem. In some situations, allowing the bags to "dry out" by passing hot, dry gas through the system may enable the cleaning system to remove enough material for the fabric filter to become operational again. Some permanent increase in pressure drop is likely to remain in this situation, however, which means increased energy cost to the plant and potentially shortened baglife.

Wash Bags

Another option that has been used with some success is to remove and **wash the bags** and then place them back in service. The cost varies according to bag size and construction, but it generally runs approximately half that of the cost for new bags. The bags are removed from the fabric filter and checked individually and the integrity of each is checked. Only those bags that appear to be in good condition are washed or dry-cleaned; other bags are replaced. Before being placed back in service, the cleaned bags are again screened to check for fabric integrity. Those bags that do not pass must also be replaced. For bag washing to be effective, only a small percentage of bags (i.e., less than 10%) can be rejected during the screening process and at least half of the expected bag life must remain. Otherwise, bag washing or dry cleaning does not appear to be a cost-effective approach.

Precoating

When the particulate matter to be captured by the fabric filter is expected to be sticky or condensible material, a **precoating** (figure 504.1) may be injected into the gas stream to coat the bags and keep this sticky material from condensing on or in the bags and blinding them. Any dry, powdered inert material may be used, but pulverized limestone is the most common. This material must be added continually to protect the bags. When limestone is used, care must be taken to prevent temperatures from falling below the moisture dewpoint. Otherwise, the limestone will "set" and blind the bags. Fly ash and other materials have also been used for precoating the bags.

504.4 CHEMICAL DEGRADATION

Bags damaged by chemical degradation generally must be replaced. Once begun, loss of fabric strength due to chemical degradation cannot be reversed. After the damaged bags are removed, consideration should be given to altering the temperature (if condensation or increased degradation is occurring at current

(Collection Inside Bag)

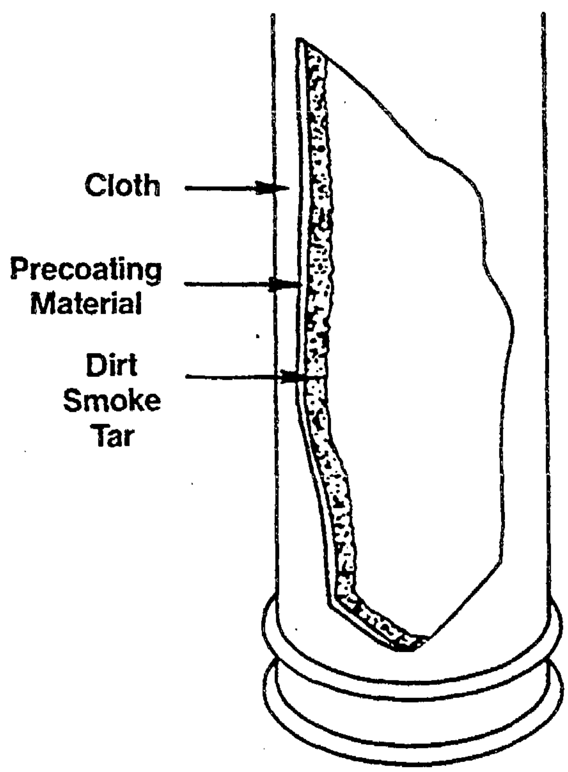


Figure 504.1 Precoating Material for Protection of Bags from Blinding 18

conditions), removing or reducing the offending constituent, or changing to a less susceptible fabric. If chemical degradation is occurring near cool surfaces in the fabric filter improving the insulation or installing windbreaks may help to correct localized chemical degradation problems.

504.5 HIGH A/C RATIO

Reduce Gas Flow

Increase Filter Area

When high A/C ratios are known to be a problem, the two most viable solutions usually are to **reduce the gas volume through the system** or to increase the filter area by installing additional fabric filtration capability. The costs of operating a system at a higher than normal design range of A/C ratios are generally related to the energy required to move the gas through an **increased resistance** (pressure drop), and the increased bag replacement costs resulting from bag abrasion, blinding, and generally shortened bag life.

Weigh Relative Costs

In some situations the **cost of operating and maintaining** the system at high A/C ratios far outweighs the cost of adding additional filter area or finding ways to reduce the gas volumes through the fabric filter system. This is particularly true when the fabric filter is applied to a combustion source. Combustion and thermal efficiency are related to the amount of excess air used in the combustion process. In a boiler, for example, the thermal efficiency decreases as the percent excess air increases. Thus, for a given boiler operating at a fixed steam production rate, more fuel is required per pound of steam at higher excess air conditions than at lower excess air conditions because of changes in thermal efficiency. The net result of burning more fuel at higher excess air levels is an increase in the quantity of flue gas produced and, therefore, an increase in A/C ratio. This in turn produces a higher pressure drop across the fabric filter and the potential for bag damage and shortened bag life.

Energy costs alone are usually substantial enough to merit changes in the operation of the unit. Personnel must look beyond the symptoms to the causes and evaluate what can be done to improve performance and reduce costs at the same time.

504.6 HIGH PRESSURE DROP

Because, as stated earlier, high pressure drop is usually a symptom of some other problem, personnel must seek the cause of the problem within the system.

504.7 BAG ABRASION

Like high pressure drop, bag abrasion is often a symptom of a problem elsewhere in the system. Causes of bag abrasion include bag-to-bag contact, poor tensioning of bags, lack of or wear of a baffle plate or other precleaning device, short or no thimbles (in some shaker and reverse-air systems), and high pressure drop as a result of high A/C ratios or bag blinding. All of these problems are related to installation, design, or operating problems, most of which are discussed elsewhere in the manual.

If the baghouse includes precleaning devices and blast plates, these should be checked periodically for wear, as they can wear out quite quickly and allow carryover of heavier, more abrasive particles to the fabric. When wear of the bags opposite the inlet is consistent in fabric filters not equipped with with **blast plates** or long thimbles, equipping the fabric filter with a method for protecting the bag may be worthwhile. For bags mounted on **thimbles**, the thimbles should be well-rounded with no sharp edges, and the bags should be properly tensioned. Again, determining the cause of the bag abrasion rather than just replacing the damaged bags may ultimately save maintenance time and money.

Blast Plates

Thimbles

504.8 DUST DISCHARGE FAILURES

Hoppers should not be used for long-term storage. Actually, continuous removal of dust from the hoppers is preferred to minimize compaction and hopper bridging. At sources operating at elevated temperatures, this can be particularly important because many dusts have better flow characteristics when they are warm than when they are cold. To assist those persons assigned to check the equipment periodically, markers should be placed on the shafts of the dust discharge system for easy confirmation that the equipment is operating.

Dust discharge systems must maintain a seal in negative pressure applications. If the fabric filter is located ahead of the fan, the system will most likely be under negative pressure. The hopper, dust discharge, and airlock system should be free of air inleakage to reduce or eliminate the resuspension of particles into the gas stream, and, at sources operated at elevated temperatures, to reduce the cooling effects attendant with inleakage. If hopper pluggage is due to cooling of the dust, eliminating inleakage, installing proper insulation, and using hopper heaters are possible corrective alternatives. This assumes that the dust discharge is adequately sized. If such is not the case or if particle characteristics change, the system may be unable to handle the quantity of dust delivered.

Vibrators

Vibrators can sometimes cause further compaction of the dust in a hopper rather than helping the dust flow, which should be considered in a decision of whether to use a vibrator. The use of a sledge hammer by plant personnel also should be approached carefully. In some situations, beating on the hopper only compacts the dust and puts dents in the hopper that provide future sites for further hopper pluggage. Taken to extreme, the hoppers can become so distorted that they remain constantly plugged or holes form that allow inleakage or fugitive emissions, depending on how the system is designed.

Fugitive Emissions

In all cases, hoppers should be cleared as soon as possible to prevent bag blinding, to avoid damage to the dust conveying system, and to minimize the **fugitive emissions** generated by manually emptying the hoppers.

504.9 SHAKER CLEANING SYSTEM FAILURES

When a system or module is isolated for cleaning, there should be no flow of gas through the system. Although damper activation can usually be checked visually during operation, the integrity of sealing cannot. Depending on the damper and fan arrangement of the system, a pressure differential across the module should show either a zero pressure drop or a static pressure equal to the outlet value. If the value measured for the isolated compartment varies from these values, some gas is still flowing through the compartment. This can make the shaking action less effective in removing the particulate matter from the bags, and bag blinding and higher than normal pressure drops may result. Although shaking action can be intensified somewhat to counteract the less effective cleaning, such action could damage the bags.

Preventive Maintenance

Shaker motors and shaker mechanisms should be kept in good operating condition. They should be checked periodically as part of a preventive maintenance plan, and any broken or worn parts should be replaced.

Bag tension and bag suspension should also be checked periodically. New bags may stretch or shrink when exposed to the gas conditions in the fabric filter. Approximately 2 weeks after initial operation, new bags should be checked for proper tension and adjusted as necessary. It should be noted that the **tension on the bag** will vary with dust cake loading. It is probably better to shake all the bags so that some valid comparison of tension can be made before adjustments are made. Records should be kept of the adjustments made and the observed dust cake release to determine if any trends or patterns are occurring.

Bag Tension

504.10 REVERSE AIR CLEANING SYSTEM

Failures of the reverse air cleaning system are usually related to poor bag tension, failure of isolation dampers, and failure of the reverse air fan(s). As in the shaker type fabric filter, isolation of the module being cleaned is essential for proper operation. It is not the reverse flow of gas that removes the dust from the bag, but the flexing action of the bag itself. Failure of the cleaning system to work in a coordinated action tends to leave an excessive dust cake on the bags, a higher pressure drop, greater bag abrasion, and possibly reduced bag life.

Fan Failure

Failure of the reverse air fan would allow the bags to hang in the fabric filter when the compartment is isolated, but no energy would be applied to flex the bags, so excessive dust cake buildup eventually occurs. The fan should be periodically checked for proper operation, and on some larger systems, the reverse-air fan motor should be monitored to ensure proper operation.

Failure to seal the isolation dampers or open the reverse-air damper can present problems. On most systems the damper drive systems (pistons, etc.) can be visually checked. In many cases, however, confirmation that the dampers are fully closed and sealed is not possible. If monitored, pressure drop across the tubesheet during the "dwell" period should show zero in. H_2O because the gas flow through the compartment would cease. If the manometer is working correctly and some pressure drop is observed, one could conclude that the dampers were not sealing properly, and maintenance should be scheduled to adjust or repair the dampers.

Bag tension should be checked periodically, particularly after bag replacement. Approximately two weeks after replacement, the tension should be checked and adjusted as necessary. Because dust layer thickness may affect bag tension, the tension on all bags should be compared after cleaning so that proper tension is provided. Excessive buildup in the bags should be noted, recorded, and evaluated for trends or patterns within the fabric filter.

504.11 PULSE JET CLEANING SYSTEM

As discussed earlier, problems with pulse jet systems that involve bent cages, leaks in bag/tubesheet seals, and bag-to-bag contacts primarily result from improper installation. This difficulty can be eliminated through proper training of personnel responsible for bag installation. Bag abrasion resulting from wear or lack of a baffle plate has also been discussed. The corrective actions discussed in this subsection focus on the compressed-air system.

Bag Length

The compressed-air pressure must fall within a specific range to generate a shock wave that traverses the **bag length** and returns, and thereby flexes the dust cake and causes its removal from the bag. The pressure range is partially related to the length of the bag; higher pressures are required for longer bags. If pressure is insufficient, the bags will not be cleaned properly and pressure drop will begin to rise. Insufficient pressure conditions can result from an undersized compressor, a leak in the system, a large number of systems being served by the compressor at one time, or somebody closing a supply-line valve.

If the compressor is inadequate to handle all the needs of the various systems, additional compressor capacity may be required. The cost of extra compressor capacity would be offset by lower energy costs resulting from the fabric filter operating with cleaner bags. The various systems supplied by the compressor(s) also should be checked to ensure that no leakage or otherwise wasteful use of compressed air is occurring. For example, a leak pulse-pipe diaphragm allows compressed air to escape and lowers compressed-air pressure.

Diffuser Insert

Too high a pressure (above 115 psig.) creates a different problem. This occurs when not enough pressure is available to clean the entire length of a long bag. The pressure can be so high at the top of the bag that it blows holes or causes tears in the fabric. One type of **diffuser insert** manufactured is supposed to help equalize the pressure wave at the top and bottom of the bag and even allow operation at a lower compressed-air pressure. Operating experience with this device seems to confirm that the tops of the bags are protected and more uniform cleaning of the bags occurs. This should extend bag life and lower energy requirements.

Bag blinding resulting from the presence of water and oil in the compressed-air supply can be solved in several ways. First, routine maintenance of the compressor can prevent worn compressor rings from passing oil into the compressed air systems. Second, a trap and/or air in-line dryer can be used to remove any water and oil. Third, the surge tank should be located such that compressed air entering the pulse pipe exits the tank from the top rather than the bottom. With this design, any water and oil that enter the surge tank will tend not to leave the tank except through a blowdown valve provided on the bottom of the tank.

Cost Considerations

Lastly, if the compressor is beyond reasonable repair, a new one should be considered. Again, **cost is important in the consideration** of whether to repair or replace a compressor or install a dryer in the system. If the cost of one or two bag changes, however, is equivalent to the cost of a new compressor and the bags are lasting less than half of their normal expected life, the cost of replacement will be offset by the extended bag life. Another set of costs often overlooked are those associated with lost production caused by the fabric filter being down and the cost of maintenance personnel to change the bags. The solution to the problem of bag blinding is to identify the cause of bag blinding and make the appropriate changes. Cost savings can be substantial. At one fabric filter installation, bags had to be changed once every 2 months because of bag blinding at an approximate cost of $5000 for bags alone. The cause of the problem proved to be a worn compressor that was losing quite a bit of oil, and the cost of replacing the compressor with one of equivalent size was approximately $5000. Even with a bag life of only 1 year (half of the expected normal bag life of 2 years), this company spent $25,000/year more on bags than necessary, and if the cost of lost production and maintenance personnel were added, the actual cost would be at least twice that amount. As has been stressed several times, identifying the cause rather than treating the symptom is usually the least-cost solution to any problem.

Diaphragm

In the pulse jet activation circuit, leakage of the **diaphragm** can cause compressed air to escape from the surge tank. This lowers overall pulse pressure, reduces cleaning efficiency, and increases fabric filter pressure drop. A continuous hiss from the leaking diaphragm is usually an indicator of this condition. Most plant maintenance personnel keep several spare diaphragm replacement kits available because repair is usually relatively simple. The solenoids that activate the various pulse-pipes are also subject to failure and are easily replaced in most designs. When these solenoids fail, the diaphragm will not open and material is allowed to build up in the row that is supposed to be cleaned. Depending on the fabric filter design, this problem may not be detected until someone checks for the activation of each row for cleaning.

The timing circuit is also subject to failure. The older fabric filters used mechanically driven and activated rotary switches to activate each solenoid. Newer designs use electronic timers to activate the cleaning system. These new systems tend to be more compact and more reliable if maintained properly. Both systems require clean, dry mountings to operate properly, and the presence of water and dust inside the timer enclosure can lead to failure of the **timer circuits.** The electronic timers also must be properly shock-mounted in a cool area. Electronic timers mounted on vibrating machinery have occasionally suffered from cracked circuit boards or loosened components as a result of the vibration. In addition, the solid-state components generally cannot withstand temperatures above 115 °F to 125 °F for extended periods of time. Failure of the timing circuit will cause the bags to blind because they cannot be cleaned.

Timing Circuit

The last problem to be discussed with regard to pulse jet systems is **pulse-pipe alignment.** When installed or replaced, the pulse pipes should be aligned over the row of bags so that the openings are centered over each bag and aimed down the centerline of the bags. The attachment technique on many pulse-pipe designs ensures this alignment. In some pipe designs, however, the pipes can be misaligned. Care should be taken to be sure these pipes are properly aligned. In addition, the end of the pipe that is away from the pulse supply must be bolted or clamped down. If this clamp is broken, pipe misalignment is likely and damage to the top of the bags can occur. Pipes that are loose usually create a rattle inside the clean-air plenum when the cleaning system is activated. Maintenance should be scheduled as soon as possible to correct this problem, as pulse pipes can break from the connectors and damage the bags.

Pipe Alignment

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Audience

This section is written **primarily for plant personnel** at a facility with a baghouse.

The maintenance discussed in the following sections is preventive maintenance. Its goal is to maintain the long term performance of the baghouse and to minimize the failure of various components that affect baghouse performance. An important aspect of preventive maintenance is routine, scheduled inspections of the baghouse, both externally and internally. These inspections include shift or daily inspections, weekly inspections, monthly or quarterly inspections, and outage inspections.

Appendix F

Typical scheduled maintenance checklists can be found in **appendix F**.

Depending on the unit's operating history and the manufacturer's recommendations, internal inspections can be performed quarterly, semiannually, or annually. As the time interval increases, the amount of action required usually increases. Daily and weekly inspections may require checks of operating parameters and general operating conditions, whereas monthly or quarterly inspections require specific actions regardless of performance of the baghouse.

Safety Procedures

A discussion of **safety procedures** is included in section 603, which covers internal inspections.

The wide range of baghouse applications makes specifications of preventive maintenance practices a difficult task. Recordkeeping is the heart of any maintenance program because it permits determination of patterns that point to the possibility of major problems on the horizon. For a baghouse, recordkeeping (see section 502 of this manual) centers on bag life and bag replacement, but other items must also be considered.

- The following is a general checklist of items that should be inspected regularly as part of a comprehensive inspection program.

- Inspect filter media for blinding, leakage, wear, slack, bag tension, loose bag clamps, or discoloration.

- Inspect the overall collector and compartment housings, hooding, and con necting ductwork for leakage, corrosion, or dust accumulation.

- Inspect all solenoid-operated pneumatic damper actuators, airlocks, and valves for proper seating, dust accumulation, leakage, synchronization, and operation.

- Inspect hopper discharge for possible bridging of dust.

- Measure the bag pressure drop. Compare frequency of cleaning with that recommended by the manufacturer.

- Inspect fan bolts (for tightness), bearings (for vibration), and temperature. Inspect for erosion or dust buildup in the housing and on the wheel. Check alignment of fan impeller with V-belt drive or coupling and driver.

- Inspect all bearings on fans, motors, dampers, etc., for lubrications and free rotation.

- Inspect foundation bolts on collector, motor, fan, etc., for tightness. Also inspect bolts on collector housing and structural members.

- Inspect access doors for leaks due to faulty gaskets or warping of doors and/or frames.

Although the inspection frequency for an individual fabric filter system depends on the type of system (shaker type, reverse-air type, etc.), and the vendor's recommendations, certain major components should be inspected on a regular basis, and any needed maintenance should be performed.

600 MAINTENANCE

601 DAILY INSPECTIONS AND MAINTENANCE

Identify Problems When Small

At least twice per shift (and perhaps as often as every 2 hours), opacity and pressure drop should be checked. Sudden changes in these values, along with those of temperature and gas volume, may indicate a problem. For example, the failure or partial failure of the cleaning system generally will cause a relatively rapid increase in pressure drop in most sytems. **Timely identification**, location, and correction of this problem can minimize operating problems and long-term effects on bag life. Although identification and subsequent correction of relatively minor problems have little effect on fabric life, some minor problems tend to turn into major failures. Thus, the operation of a baghouse should be tracked on a daily basis to assure early detection of any problem. The ability to perform on-line maintenance depends on the design of the control equipment.

Routine checks of the baghouse include pressure drop (and patterns if a pressure change indicator and recorder are used), opacity patterns, dust discharge operation, and external checks of the cleaning system operation. Other factors that can be checked include temperature (range) and fan motor current. If a check of these factors reveals a sudden change, maintenance should be scheduled as soon as possible.

602 WEEKLY INSPECTION AND MAINTENANCE

Visual Checks

Lubrication

The extent of the weekly maintenance program depends greatly on access and design of the baghouse. Where possible, quick **visual inspections** should be conducted. However, not all systems or processes are amenable to this type of review. A weekly **lubrication** schedule should be established for most moving parts. Manometer parts should be blown clear, and temperature monitors should be checked for proper operation.

602.1 SHAKER TYPE BAGHOUSES

The operation of isolation dampers should be checked, along with the operation of the shaker system. The intensity of shaking should be relatively uniform throughout the compartment. Bag tension should be checked, and any fallen bags should be noted and repaired. The presence of any dust deposits on the clean side of the tubesheet also should be noted, as well as any holes or leaks in the bags.

602.2 REVERSE AIR BAGHOUSES

The operation and sealing of the isolation and reverse air dampers should be checked. Each compartment should be checked for proper bag tension during reverse air operation, and any fallen bags should be noted and repaired. The presence of dust deposits on the clean side of the tubesheets should be noted to determine if there are any holes and leaks in the bags and if the seals are tight. Tubesheets should be cleaned periodically to keep deposits from building up around the bags.

602.3 PULSE JET BAGHOUSES

On the dirty side of the tubesheet, bags should be checked for relatively thin and uniform exterior deposits. Bags also should be checked for bag-to-bag contact (points of potential bag wear). On the clean side of the tubesheet, each row of bags should be examined for leakage or holes.

Deposits on the underside of the blowpipes and on the tubesheet may indicate a bag failure. The cleaning system should be activated (the inspector should use hearing protection), and each row of bags should fire with a resounding "thud." The blowpipes should remain secure, and there should be no evidence of oil or water in the compressed air supply. The surge tank or oil/water separator blowdown valve should be opened to drain any accumulated water. Misaligned blowpipes should be adjusted to prevent damage to the upper portion of the bag. The compressed air reservoir should be maintained at about 90 to 120 psi.

603 MONTHLY, QUARTERLY OR OUTAGE INSPECTION AND MAINTENANCE

Beyond weekly inspections, the requirements become very site-specific. Clear-cut schedules cannot be established for such items as bag replacement and general maintenance of the fabric filter. Some items, however, may warrant monthly or quarterly inspections, depending on site-specific factors.

Checks to be made will be outlined in section 603.4. Because the checks made on a monthly or quarterly schedule may require shutdown of the baghouse, the procedures for doing so will be given before the internal inspection procedures.

603.1 SHUTDOWN PROCEDURES

Dewpoint Conditions

Dewpoint conditions and dust removal from the fabric filter are the primary concerns during shutdown. Failure to follow recommended shutdown procedures also can result in early bag failure. Avoiding dewpoint conditions through system purging is of top priority; bag cleaning and hopper emptying are lower-priority items.

When processes operate on a daily cycle, the last operation of the day should be to purge moisture and acidic materials from the baghouse without passing through dewpoint. For example, an asphalt plant might allow the drier to operate for several minutes with the burner on after the aggregate has been removed from the drum to remove moisture from the fabric filter. Ambient air could then be drawn through the system to purge the remaining combustion products from the baghouse. Even well-insulated baghouses usually have trouble maintaining temperatures above dewpoint for more than several hours; therefore, it is advisable to purge these systems when long idle periods are expected.

Dust Removal

Upon shutdown, at least one or two complete cleaning cycles should be allowed in compartmented baghouses, and 5 to 20 minutes of cleaning in pulse jet systems. **Removing the dust** from the bags on this fashion will help prevent blinding of the bags. Continuing to operate the hopper discharge system while the cleaning system is in operation will minimize the chance of hopper pluggage.

When **emergency shutdowns** of the baghouse are necessary because of high temperatures, spark detection, of other process upsets, the fabric filter is usually

Emergency Shutdown

bypassed to prevent failures and to protect the system from damage. For such major problems as fires in the hoppers or on the bags, however, it is probably better to let them burn out rather than to cut off the gas flow immediately. Allowing the ignition source into a baghouse without any gas flow may cause an explosion. Also, adding water to a burning baghouse or to a hopper fire is not advisable. In some situations, the addition of water under oxygen starved conditions will hydrolyze the water and form hydrogen, which can create the potential for an explosion within the baghouse. The baghouse manufacturer and insurance carrier should be contacted whenever a known potential for fires or explosions exists.

Other process failures may necessitate only temporary bypassing of the baghouse, and the operation can be restored in a matter of minutes. In these cases, the fabric filter generally does not have to be shut down completely and purged. If the upset cannot be corrected within a reasonable amount of time, however, shutdown and the subsequent startup of the baghouse may then be necessary to prevent dewpoint problems.

It is important to note that bypassing the baghouse during startup, soot blowing, or an emergency may not be acceptable to the applicable regulatory agency. Such occurrences should be investigated and accounted for during the design stages of development.

603.2 CONFINED-AREA ENTRY

A confined space is an enclosure in which dangerous air contamination cannot be prevented or removed by natural ventilation through some opening of the space. Access to the enclosed area also may be restricted so that it is difficult for personnel to escape or to be rescued. Common examples of confined spaces are storage tanks, tank cars, or vats. Depressed areas like trenches, sumps or wells also may have poor ventilation and may be considered confined spaces. A baghouse falls under the general definition of confined space, and so requires special procedures and precautions with regard to entry.

Potential dangers presented by confined space fall into three categories: oxygen deficiency, explosion, and exposure to toxic chemicals and agents.

Oxygen deficiency is the most common hazard. Any gas introduced into a confined space displaces the atmosphere and reduces the oxygen content below the normal value of 20.8 percent. Out-gassing of combustible gases (methane, hydrogen sulfide,organic vapors and others) from collected particulate can result in local pockets with reduced oxygen levels. Further, application of the baghouse to combustion sources (utility boilers, industrial boilers, cement kilns, recovery boilers, incinerators) produces an atmosphere that is extremely low in oxygen content (2 to 10 percent). Purging of the unit during cooling does not always completely replace the flue gases with ambient air, and local pockets may remain.

Oxygen Deficiency

Explosive atmospheres can be created in confined spaces by the **evaporation of volatile components** or improper purging of the baghouse when the process is shut down. Three elements are necessary to initiate an explosion: oxygen, a flammable gas or vapor, and an ignition source. A flammable atmosphere is defined as one in which a gas concentration is between two extremes: the lower explosive limit (LEL) and the upper explosive limit (UEL). A mixture of gas and oxygen in a concentration between these two values can explode if a source of ignition is present. With regard to baghouse inspection and maintenance, explosive gases normally consist of methane, hydrogen, carbon monoxide, and mixed organic vapors. The gases most commonly present at baghouse shutdown are carbon monoxide and methane.

Explosive Limits

Possible sources of ignition include cigarettes, matches, welding, cutting torches, and grinding equipment. Sparks can also be generated by static electricity. The best means of **preventing explosion** is to dilute the flammable gas below the LEL by ventilation. It is not safe to assume that a source of ignition can be eliminated and to allow work to continue in a potentially explosive atmosphere.

Work in a confined area may release flammable gases that, once released, can increase in concentration. Constant ventilation should be provided to maintain the concentration below LEL.

Because many vapors are heavier than air, pockets of flammable gases also may develop. An effective monitoring program checks concentrations at multiple locations and times during the exposure period.

Depending on the application of the baghouse, collected dust may contain toxic chemicals or harmful physical agents. These compounds may exist in the system or be created as a result of operations in the confined area. Inhalation, ingestion, or skin contact can have adverse health effects. Most agents have threshold limit doses below which harmful effects do not occur. Exposure above these threshold doses can cause acute or chronic symptoms, depending on the compound.

Toxic Chemicals

A quantitative assessment of each compound and the threshold dose levels must be made before anyone enters the baghouse. Typical **toxic chemicals** or species in the baghouse environment include carbon monoxide (CO), hydrogen sulfide (H_2S), total reduced sulfur (TRS) gases, arsenic, cadmium, beryllium, lead, alkali, and acids. If repair work is being conducted, organic solvents, zinc, or cadmium also may be present.

Entry may be permitted within certain limitations provided the person is equipped with appropriate approved respiratory protection. An assessment of the hazard, concentration, permissible exposure, and protective equipment must be made before anybody is allowed to enter the equipment.

Each facility must establish a confined-space entry policy that includes recognition of the hazards, atmospheric testing and analysis, ventilation requirements, selection and use of protective equipment, training and education of personnel, and administrative procedures.

An important component of the policy is recognition of the potential hazard, which requires complete knowledge of the industrial process and wash area. A cursory examination cannot prevent serious deficiencies; a detailed analysis is recommended.

Hazard Recognition

The second policy component involves **air monitoring**. An initial certification of gaseous concentrations must be made before entry is permitted. This certification must be made by a qualified safety officer with properly calibrated and maintained equipment. In general, a permit to enter (with a time limit) may be issued and displayed at the point of entry. Assuming that oxygen and gas levels do not change with time can be dangerous; an effective program should include periodic reevaluations of concentrations after initial entry.

Gas monitoring should be conducted to determine percent oxygen, percent lower explosive limit, hydrocarbon concentration, and carbon momoxide levels. If hydrogen sulfide or other toxic gases are suspected, additional analyses may be conducted with detection tubes or continuous gas samplers. The use of continuous gas samplers with an audible alarm is recommended. The initial measurements should be performed according to the following suggested measures:

Air Monitoring

1. The baghouse to be entered should be emptied, purged, and ventilated to the maximum extent possible. All entry ports should be opened to facilitate mixing. All electrical and mechanical equipment must be completely isolated by closing dampers, using guillotine dampers, or installing blanks.

2. A **gas tester should check** the vessel's oxygen content, explosivity, and a toxic chemical concentration by first sampling all entry ports and then sampling inside the space with probes (while tester remains outside). Caution should be used when testing for combustible gases, as many meters need an oxygen level close to ambient levels to operate correctly. This is one reason that the space should be purged and vented before testing. Voids, sub-enclosures, and other areas where pockets of gas could collect should also be tested.

3. When initial gas test results show that the space has sufficient oxygen, the gas tester can enter the space and complete the initial testing by examining areas inaccessible from outside the shell. The tester should wear an air supplied positive pressure respirator during these measurements. Special care should be taken to test all breathing zone areas.

4. If the results of the initial tests show that a flammable atmosphere still exists, additional purging and ventilation are required to lower the concentration to ten percent of the LEL before entry may be permitted.

5. If testing shows an oxygen deficient atmosphere or toxic concentrations, all personnel entering the space must use an appropriate air supplied respirator.

After the initial gas testing has been performed, dust, mists, fumes, and any other chemical agents present should be evaluated by either an industrial hygienist or a trained technician. The results will indicate if additional control measures are necessary. Physical agents such as noise, heat, and radiation must also be evaluated, and if any are present, the appropriate measures (such as providing ear protection or rotating employees) should be instigated.

The specified respiratory protection should be based on the hazard assessment.

Additionally, eye protection is necessary to prevent dust from entering the eyes. Goggle-type protection is generally not effective because of the inability of the frames to form a tight seal against the worker's face. Effective **eye protection** consists of full-face protection, a snorkling mask, or eye goggles.

Eye Protection

Skin contact with dust collected in a baghouse can result in burns or irritation. The dust may be acidic, alkaline, hygroscopic, or abrasive. Workers can **limit skin contact** area and thus prevent potential irritation by wearing long-sleeved shirts and gloves during internal inspections.

Skin Protection

603.3 HOPPER ENTRY

Hoppers present special safety hazards.

Workers often remove the lock and open hopper doors prematurely to cool a unit quickly or to clear hopper pluggage. The main danger in opening the doors is the discharge of **hot ash** impounded in the hopper.

Hot Ash

In the opening of hopper doors, the inspectors must take care to ensure that no **accumulation of collected dust** is impounded behind the inner door. Before hopper doors are opened, an internal inspection must also be made from the top of the collecting surfaces to be certain no buildup is present in the corners of the unit or in the valleys of the pyramidal hoppers. Dust that has accumulated in valleys or corners may break loose during entry into the hopper and cause minor injury. In some cases, more serious injury or suffocation can result from dust falling on and burying personnel.

Dust Accumulation

Entry into hoppers for any reason other than maintenance should be avoided. Maintenance should first be attempted from outside the hopper. If the hopper must be entered, steps should be taken to dislodge and discharge dust before such entry. This can be accomplished by mechanical vibration (vibrators, hammers), poking, prodding, or air lancing. Complete removal can be accomplished by washing with a high pressure water hose.

Removal of accumulated dust must not be attempted from inside the hopper. Care should be taken to ensure that any dust accumulation in the inlet and outlet plenums (nozzles) is removed. This material can become dislodged, move en masse into the inlet or outlet field hoppers, and completely fill the hopper. Finally, before the hopper doors are opened, the **inlet plenum** should be checked, and any dust should be moved into the hopper for discharge.

Inlet Plenum

600 MAINTENANCE

Hopper doors should not be opened during baghouse operation because hot ash could overflow onto the operator. This ash is very fluid, and it could quickly engulf and severely burn a person.

Safety Chains

All hopper doors should be equipped with **safety chains** or double latches to prevent complete opening upon release. This can slow the loss of ash in the event of accidental opening of a full hopper.

Most hopper inner doors have design features, that, if properly used, will ensure that no door is opened when dust is impounded behind it. First, a pipe coupling with a plug that can be removed should be installed in the door; this would allow visual verification. Second, a pressure-type latch should be used that allows a portion of the door seal to be released to create a gap between the door and sealing jam. This partial release would allow accumulated dust to flow out and indicate a partially full hopper without the possibility of the door opening fully.

One way to determine the fullness of a hopper is to strike the access door with a hammer. If the hopper is empty, this will produce a resounding ring, indicating that there is no material against the inside surface; if the hopper is full, the blow will produce a dull thud.

A further warning regarding hopper entry involves the use of handgrips and footholds in the hopper. Because of the possible dust buildup on protruding objects, manufacturers have purposely avoided the use of handholds and footholds in hopper interiors. The steep valley angles and and dust layer create the potential for a fall and injury for persons entering the door. Because of the angles and small door openings, abrasion and back injuries top the potential injury list. Outside access equipment (scaffolds, ladders, handholds) should be installed to minimize the awkwardness of hopper door entry.

Radiation Source

If nuclear hopper level detectors are used, the beam (which is a **radiation source**) should be shielded from the outside prior to entry. This shielding should be part of the interlock system for the doors.

Hopper evacuation systems (screws, drag chains, agitators) should not be operated when personnel are inside the hopper area or in an area from which they could fall inside the hoppers.

603.4 INTERNAL INSPECTION

Inleakage

Items to be checked include door gaskets and airlock integrity to prevent excessive **inleakage** (both air and water) into the enclosure. Any defective seals should be replaced. Baffles or blast plates should be checked for wear and replaced as necessary, as abrasion can destroy the baffles.

Fluorescent Dye

Some facilities prefer to use **fluorescent dye** to check the integrity of the bags and bag seals. Bags should be checked for tears, pinholes, and sagging (inadequate tension). Staining and stiffening of the dirty fabric indicates excessive caking caused by moisture condensation or chemical reactions. The latter condition leads to fabric blinding and excessive pressure loss as well as to fabric failure.

Any defective bags should be replaced, and leaking seals should be corrected. Bag failures tend to occur shortly after installation and near the end of a bag's useful life. A record of bag failures and replacements is invaluable for identifying recurrent problems and indicating when the end of bag life has been reached.

Bag Failure Charts

The **bag failure charts** for the baghouse should be examined. If a distinct spatial pattern is apparent, the damage may be due to abrasion (inlet gas blasting, inlet swirling, or rubbing against internal supports). The date of the bag removal and the elevation of the apparent damage (T-top, M-middle, B-bottom) enable identification of many common modes of failure. By using such charts, operators have been able to minimize both excess emission incidents and bag replacement cost. A rapid increase in the rate of failure often suggests significant deterioration of fabric strength due to chemical attack or high temperature excursions.

Initial bag failures usually occur because of installation errors or bag manufacturing defects. When new bags are installed, a period with few or no bag failures is normally expected unless serious design or operation problems exist. As the bags near the end of their useful life, however, the number of bag failures may increase dramatically. When weighed against factors such as downtime for rebagging, the cost of new bags, and the risk of limited production as the result of keeping the old bags in service, the most economical approach may be just to replace all the bags at one time to eliminate or minimize failure rate.

In some cases, bags can be washed or drycleaned and reused, eg., when dewpoint limits are approached or the bags are blinded in some manner. This is generally an economically viable option when more than half a bag's normal life expectancy remains. Although cleaning may shorten bag life somewhat, sometimes it is economically more feasible to clean bags than to replace them.

Rip Test

When bags are removed from service, a simple **rip test** should be performed. If it is possible to rip the cloth by inserting a screwdriver and pulling, the bag damage probably was a result of chemical attack, high temperature excursions, moisture attack, or routine fabric exhaustion. Most fabrics damaged by abrasion-related problems cannot be ripped, even near the site of damage.

Improper discharge of material from the bags can often be confirmed by noting that bags are full of material one or more diameters up from the bottom.

Seepage or Bleeding

Dust **seepage or bleeding** and/or pinhole leaks are evidenced by dust deposits on the clean side of the fabric. Anything more than a trace of material on the clean-side tube sheet is indicative of emissions that are probably much higher than baseline levels from the compartment being viewed. Remember that most of the dust in the clean-side is carried out because of the relatively high gas velocities.

Deposits on Floor Plates

A **dust layer more than a quarter inch thick on the floor plates**, or isolated piles of dust suggests excess seepage and/or torn or missing bags. Inspection of the inlet plenum, including bag interior, will reveal any dust buildup on bags and distribution plates. As a rule of thumb for smaller baghouses, if the amount of dust on a bag after cleaning is more than twice the weight of the new (unused) bag, insufficient cleaning is indicated. The condition of solenoid valves, poppet valves, mechanical linkages, and bag clamps are also indicated.

Misalignment

In the case of pulse jet type baghouses, bag and cage assemblies should be carefully inspected upon removal. **Often the point of bag failure** is next to a sharp point on the support cage. Premature failure may also be caused by cages that do not provide enough support for the fabric. If all the bags have failed at the top, the compressed-air nozzles may be misaligned. This can cause the pulse to be directed at a narrow area at the top of the bag.

Snap Ring Leakage

In reverse air and shaker type fabric filters, the presence of snap ring leakage is often indicated by enlarged craters in the clean-side deposits around the poorly sealed bags. Holes and tears can sometimes be located by the shape of dust deposits next to the holes. A sagging or slack bag can result in the bag folding over the bottom thimble connection and creating a pocket in which accumulated dust can rapidly abrade and tear the fabric. Slackness also prevents effective cleaning action.

603.5 STARTUP PROCEDURES

Improper startup can adversely affect many baghouses. Most often these adverse effects will be reflected as an increase in pressure drop or a shortening of bag life, both of which increase the cost of operating the baghouse.

For new baghouses, a complete check of all the components is recommended prior to operation. Any necessary repairs or corrections are usually easier to make while the baghouse is still clean. This component check should include operating the cleaning system, the dust-discharge system, and the isolation dampers and fans. It should also include passing clean ambient air through the system to confirm that all bags are properly installed. As a final check, **fluorescent dye** may be injected into the system to check for proper sealing of the tubesheet and bags. The use of fluorescent dye is usually reserved until some small amount of dust cake is built up on the bags so that the dust will not bleed through the bags.

Fluorescent Dye

New bags are prone to **abrasion** if subjected to high dust loadings and full-load gas flows. This is of particular concern during the initial start-up, as new bags do not have the benefit of a dust buildup cake to protect the fibers from abrasion or to increase their resistance to gas flow. Introducing a full gas flow at high dust loadings can allow the particulate matter to impinge on the fabric at high velocity and result in abrasion that may shorten bag life. In addition, the dust may penetrate so deeply into the fabric that the cleaning system cannot remove it, and an increased, steady pressure drop results.

Abrasion

Two methods are available to prevent this problem with new bags. The first involves introducing a **reduced gas volume** into the fabric filter at a lower mass loading (if possible) to allow the dust cake to build up gradually and gently. This prevents the particles from impacting the new bag fibers at full bag velocity. All dampers and/or inlet vanes should be partially closed during startup to reduce power consumption. After the operating fan speed has been attained and the overall system temperature approaches the operating level, the damper should be opened carefully to avoid motor overload.

Reduced Gas Flow

The second method involves the use of a **precoat material** to provide a protective filter cake before the process gas stream is introduced. The precoat material may be the same dust that will be filtered during normal operation or some other dust that will provide suitable cake-release properties. Examples of precoat materials include fly ash and pulverized limestone. Although the use of a

Precoating

precoat material may be part of normal operation or routine startup procedures, it is also recommended when new bags are installed, when an abrasive dust situation exists, when the bag fabric has a low abrasion resistance, and when particle bag changeouts occur.

Dewpoint

Dewpoint (both water and acid, if applicable) is a major concern during startup. The presence of moisture in the gas stream usually does not present a problem as long as the moisture is not allowed to condense within the baghouse. The introduction of warm, moist gas into a cool or cold baghouse can cause condensation on the bags or on the baghouse shell. This moisture may cause bag blinding and a situation referred to as "mudded" bags. Although some dusts can be heated, dried, and then removed from the bags, most will remain as a solid and impermeable dust cake that produces excessively high pressure drops.

Special care must be taken with the use of some precoat materials (such as limestone) because these materials tend to solidify when allowed to become moist. Preheating the fabric filter to a sufficiently high temperature to prevent condensation is a practical alternative in some cases. For example, baghouses used in asphalt plants can be preheated by firing the dryer without aggregate until the temperature at the fabric filter outlet exceeds the dewpoint. In the case of compartmented baghouses, individual compartments can be preheated and brought on-stream as the process rate increases.

Acid dewpoint may be important on some combustion processes (most notably using those sulfur-bearing fuels). The acid dewpoint depends on the amount of moisture and acidic material in the gas stream. Acid dewpoint conditions can lead to corrosion of the baghouse components, sticky particulate and cake release problems, and acid attack on some fabrics. One of the most well known but sometimes overlooked combinations that result in fabric attack is the use of Nomex fabric with a gas stream high in sulfuric acid. The sulfuric acid will attack the aramid structure of the Nomex fabric and cause a loss of bag strength and fabric failure. If operators are not made aware of the need to avoid acid dewpoint conditions, bag failure will occur frequently.

Poor Combustion

Another problem (often associated with combustion sources) is unstable combustion during startup. **Poor combustion** can produce substantial carbon carryover, which may result in sticky particulate. This situation also can create the potential for fires in the fabric filter when a combustion source and an adequate supply of oxygen are available. Because fires on the bags and in the hoppers tend to destroy the fabric and necessitate bag replacement, hoppers should be emptied continually during startup. Coal-fired boilers in which oil is used during startup present problems in the areas of minimizing emissions and protecting the fabric filter. Bypassing the baghouse until stable coal operation is achieved, preheating the baghouse, and bringing only the minimum number of compartments needed into service when stable combustion has been achieved are all ways of avoiding operating problems. Continuing precoating of the bags can help to prevent sticky (condensable) soot from fouling the bags during startup.

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APPENDIX B

Appendix B contains two rules presented as samples of particulate matter emission-limiting rules. The rules shown here are South Coast AQMD Rules 404 (Particulate Matter - Concentration) and 405 (Solid Particulate Matter - Weight).

(Adopted May 7, 1976) (Amended October 5, 1979)
(Amended February 7, 1986)

RULE 404. PARTICULATE MATTER - CONCENTRATION

(a) A person shall not discharge into the atmosphere from any source, particulate matter in excess of the concentration at standard conditions, shown in Table 404 (a).
Where the volume discharged is between figures listed in the table, the exact concentration permitted to be discharged shall be determined by linear interpolation.
The provisions of this subsection shall not apply to any equipment completed and put into service before July 1, 1976 in the Palo Verde and Joshua Tree areas.
Before July 1, 1983, liquid sulfur compounds shall not be included as particulate matter discharged from petroleum coke calciners.

(b) A person shall not discharge into the atmosphere from any source, particulate matter in excess of 450 milligrams per cubic meter (0.196 grain per cubic foot) in discharged gas calculated as dry gas at standard conditions.
The provisions of this subsection shall apply only to any equipment completed and put into service before July 1, 1976 in the Palo Verde and Joshua Tree areas.

(c) The provisions of this rule shall not apply to emissions resulting from the combustion of liquid or gaseous fuel s in steam generators or gas turbines.

(d) For the purposes of this rule, emissions shall be averaged over one complete cycle of operation or one hour, whichever is the lesser time period.

(e) The provisions of this rule shall not apply to the use of equipment which complies with the emission limits specified in Rule 1112.1.

TABLE 404(a)

Volume Discharged Calculated as Dry Gas At Standard Conditions		Maximum Concentration of Particulate Matter Allowed in Discharged Gas Calculated as Dry Gas at Standard Conditions		Volume Discharged Calculated as Dry Gas At Standard Conditions		Maximum Concentration of Particulate Matter Allowed in Discharged Gas Calculated as Dry Gas at Standard Conditions	
Cubic Meters Per Minute	Cubic Feet Per Minute	Milligrams Per Cubic Meter	Grains Per Cubic Foot	Cubic Meters Per Minute	Cubic Feet Per Minute	Milligrams Per Cubic Meter	Grains Per Cubic Foot
25 or less	883 or less	450	0.196	900	31780	118	0.0515
30	1059	420	.183	1000	35310	113	.0493
35	1236	397	.173	1100	38850	109	.0476
40	1413	377	.165	1200	42380	106	.0463
45	1589	361	.158	1300	45910	102	.0445
50	1766	347	.152	1400	49440	100	.0437
60	2119	324	.141	1500	52970	97	.0424
70	2472	306	.134	1750	61800	92	.0402
80	2825	291	.127	2000	70630	87	.0380
90	3178	279	.122	2250	79460	83	.0362
100	3531	267	.117	2500	88290	80	.0349
125	4414	246	.107	3000	105900	75	.0327
150	5297	230	.100	4000	141300	67	.0293
175	6180	217	.0947	5000	176600	62	.0271
200	7063	206	.0900	6000	211900	58	.0253
250	8829	190	.0830	8000	282500	52	.0227
300	10590	177	.0773	10000	353100	48	.0210
350	12360	167	.0730	15000	529700	41	.0179
400	14130	159	.0694	20000	706300	37	.0162
450	15890	152	.0664	25000	882900	34	.0148
500	17660	146	.0637	30000	1059000	32	.0140
600	21190	137	.0598	40000	1413000	28	.0122
700	24720	129	.0563	50000	1766000	26	.0114
800	28250	123	.0537	70000 or more	2472000 or more	23	.0100

(Adopted May 7, 1976) (Amended February 7, 1986)

RULE 405. SOLID PARTICULATE MATTER - WEIGHT

(a) A person shall not discharge into the atmosphere from any source, solid particulate matter including lead and lead compounds in excess of the rate shown in Table 405 (a). Where the process weight per hour is between figures listed in the table, the exact weight of permitted discharge shall be determined by linear interpolation.
The provisions of this subsection shall not apply to any equipment completed and put into service before July 1, 1976, in the Palo Verde and Joshua Tree areas.

(b) A person shall not discharge into the atmosphere in any one hour from any source, solid particulate matter including lead and lead compounds in excess of 0.23 kilogram (0.5 pound) per 907 kilograms (2000 pounds) of process weight.
For the purposes of this subsection only, process air shall be considered to be a material introduced into the process when calculating process weight.
The provisions of this subsection shall apply only to equipment completed and put into service before July 1, 1976 in the Palo Verde and Joshua Tree areas.

(c) For the purposes of this rule, emissions shall be averaged over one complete cycle of operation or one hour, whichever is the lesser time period.

(d) The provisions of this rule shall not apply to the use of equipment which complies with the emission limits specified in Rule 1112.1.

TABLE 405(a)

Process Weight Per Hour		Maximum Discharge Rate Allowed for Solid Particulate Matter (Aggregate Discharged From All points of Process)		Process Weight Per Hour		Maximum Discharge Rate Allowed for Solid Particulate Matter (Aggregate Discharged From All. points of Process)	
Kilograms Per Hour	Pounds Per Hour	Kilograms Per Hour	Pounds Per Hour	Kilograms Per Hour	Pounds Per Hour	Kilograms Per Hour	Pounds Per Hour
100 or less	220 or less	0.450	0.99	9000	19840	5.308	11.7
150	331	0.585	1.29	10000	22050	5.440	12.0
200	441	0.703	1.55	12500	27560	5.732	12.6
250	551	0.804	1.77	15000	33070	5.982	13.2
300	661	0.897	1.98	17500	38580	6.202	13.7
350	772	0.983	2.17	20000	44090	6.399	14.1
400	882	1.063	2.34	25000	55120	6.743	14.9
450	992	1.138	2.51	30000	66140	7.037	15.5
500	1102	1.209	2.67	35000	77160	7.296	16.1
600	1323	1.340	2.95	40000	88180	7.527	16.6
700	1543	1.461	3.22	45000	99210	7.738	17.1
800	1764	1.573	3.47	50000	110200	7.931	17.5
900	1984	1.678	3.70	60000	132300	8.277	18.2
1000	2205	1.777	3.92	70000	154300	8.582	18.9
1250	2756	2.003	4.42	80000	176400	8.854	19.5
1500	3307	2.206	4.86	90000	198400	9.102	20.1
1750	3858	2.392	5.27	100000	220500	9.329	20.6
2000	4409	2.563	5.65	125000	275600	9.830	21.7
2250	4960	2.723	6.00	150000	330700	10.26	22.6
2500	5512	2.874	6.34	175000	385800	10.64	23.5
2750	6063	3.016	6.65	200000	440900	10.97	24.2
3000	6614	3.151	6.95	225000	496000	11.28	24.9
3250	7165	3.280	7.23	250000	551200	11.56	25.5
3500	7716	3.404	7.50	275000	606300	11.82	26.1
4000	8818	3.637	8.02	300000	661400	12.07	26.6
4500	9921	3.855	8.50	325000	716500	12.30	27.1
5000	11020	4.059	8.95	350000	771600	12.51	27.6
6000	13230	4.434	9.78	400000	881800	12.91	28.5
7000	15430	4.775	10.5	450000	992100	13.27	29.3
8000	17640	5.089	11.2	500000 or more	1102000 or more	13.60	30.0

APPENDIX C

Appendix C contains ARB Method 5 - Determination of Particulate Matter Emissions from Stationary Sources.

The Method presented here is as referenced in CCR, Title 17, § 94105. This Method was adopted 6/29/83, and last amended 1,7,88.

METHOD 5 - DETERMINATION OF PARTICULATE MATTER EMISSIONS FROM STATIONARY SOURCES

1. Principle and Applicability

1.1 Principle: Particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120 ± 14°C (248 ± 25°F) or such other temperature as specified by an applicable subpart of the standards or approved by the Control Agency's Authorized Representative for a particulate application. The particular mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water.

Since the definition of particulate matter is not consistent in all rules, the particulate matter catch should be itemized by weight as follows: (1) Filter Catch, (2) Probe Catch, (3) Impinger Catch, and (4) Solvent Extract to allow adjustment of the particulate matter determination to be consistent with the applicable regulation.

1.2 Applicability: This method is applicable for the determination of particulate emissions from stationary sources.

2. Apparatus

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 5-1. Complete construction details are given in APTD-0581 (Citation 2 in Section 7); commercial models of this train are also available. For changes from APTD-0581 and for allowable modifications of the train shown in Figure 5-1, see the following subsections.

The operating and maintenance procedures for the sampling train are described in APTD-0576 (Citation 3 in Section 7). Since correct usage is important in obtaining valid results, all users should read APTD-0576 and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

2.1.1 Probe Nozzle. Stainless steel (316) or glass with sharp, tapered leading edge. The angle of taper shall be ≤30° and the taper shall be on the outside to preserve a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Control Agency's Authorized Representative. If made of stainless steel, the nozzle shall be constructed from seamless tubing; other materials of construction may be used, subject to the approval of the Control Agency's Authorized Representative.

A range of nozzle sizes suitable for isokinetic sampling should be available, e.g., 0.32 to 1.27 cm (1/8 to 1/2 in.) or larger if higher volume sampling trains are used inside diameter (ID) nozzles in increments of 0.16 cm (1/16 in). Each nozzle shall be calibrated according to the procedures outlined in Section 5.

2.1.2 Probe Liner. Borosilicate or quartz glass tubing with a heating system capable of maintaining a gas temperature at the exit end during sampling of 120 ± 14°C (248 ± 25°F), or

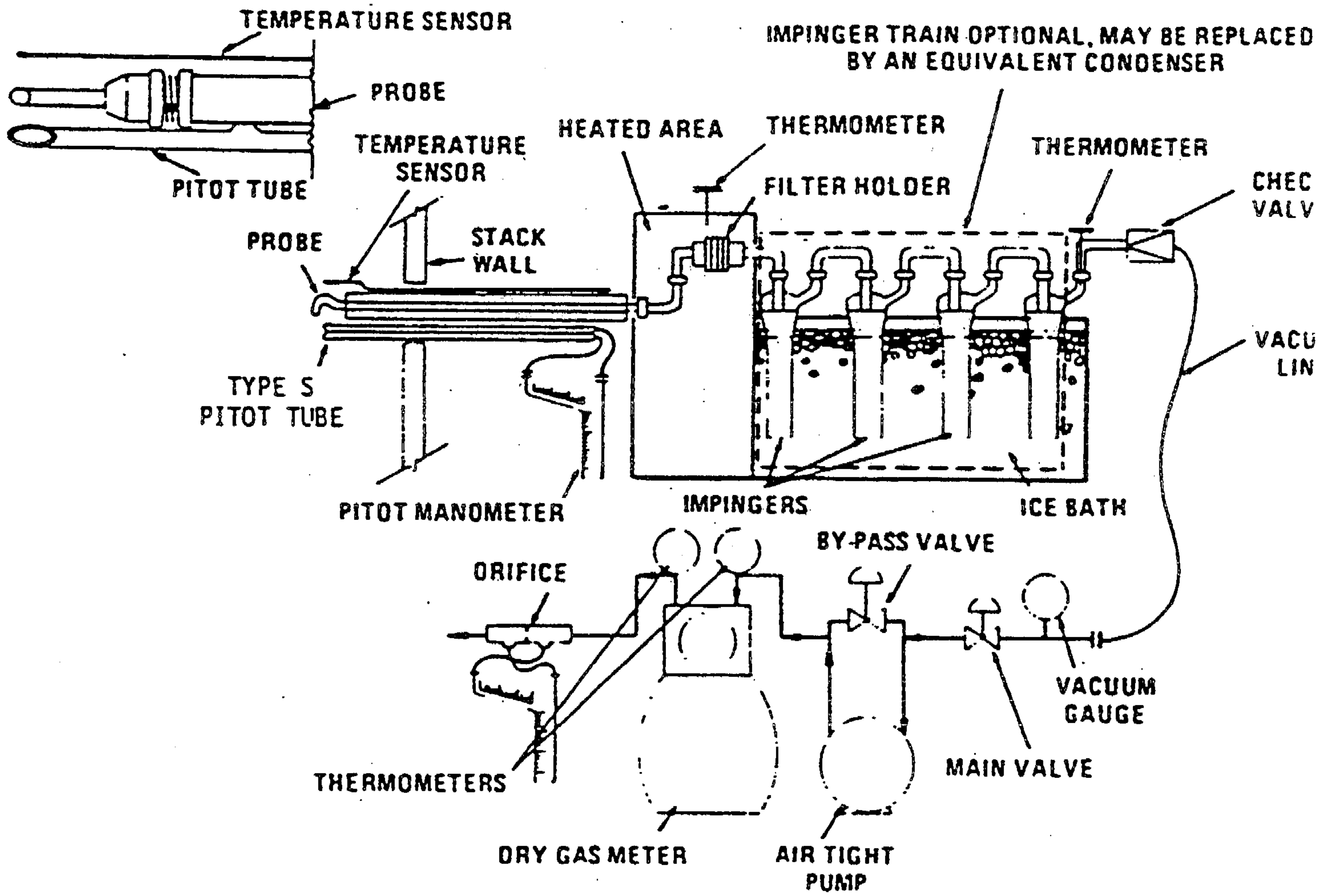

Figure 5.1 Schematic of Method 5 sampling train.

such other temperature as specified by an applicable subpart of the standards or approved by the Control Agency's Authorized Representative for a particular application. (The tester may opt to operate the equipment at a temperature lower than that specified.) Since the actual temperature at the outlet of the probe is not usually monitored during sampling, probes constructed according to APTD-0581 and utilizing the calibration curves of APTD-0576 (or calibrated according to the procedure outlined in APTD-0576) will be considered acceptable.

Either borosilicate or quartz glass probe liners may be used for stack temperatures up to about 480°C (900°F); quartz liners shall be used for temperatures between 480° and 900°C (900 and 1,650°F). Both types of liners may be used at higher temperatures than specified for short periods of time, subject to the approval of the Control Agency's Authorized Representative. The softening temperature for borosilicate is 820°C (1,508°F), and for quartz it is 1,500°C (2,732°F).

Whenever practical, every effort should be made to use borosilicate or quartz glass probe liners. Alternatively, metal liners (e.g., 316 stainless steel, Incoloy 825,[1/] or other corrosion resistant metals) made of seamless tubing may be used, subject to the approval of the Control Agency's Authorized Representative.

[1/]Mention of trade names or specific products does not constitute endorsement by the Air Resources Board.

2.1.3 Pitot Tube. Type S, as described in Section 2.1 of Method 2, or other device approved by the Control Agency's Authorized Representative. The pitot tube shall be attached to the probe (as shown in Figure 5-1) to allow constant monitoring of the stack gas velocity. The impact (high pressure) opening plane of the pitot tube shall be even with or above the nozzle entry plane (see Method 2, Figure 2-6b) during sampling. The Type S pitot tube assembly shall have a known coefficient, determined as outlined in Section 4 of Method 2.

2.1.4 Differential Pressure Gauge. Inclined manometer or equivalent device (two), as described in Section 2.2 of Method 2. One manometer shall be used for velocity head (P) readings, and the other, for orifice differential pressure readings.

2.1.5 Filter Holder. Borosilicate glass, with a glass frit filter support and a silicone rubber gasket. Other materials of construction (e.g., stainless steel, Teflon, Yiton) may be used, subject to approval of the Control Agency's Authorized Representative. The holder design shall provide a positive seal against 1eakage from the outside or around the filter. The holder shall be attached immediately at the outlet of the probe (or cyclone, if used).

2.1.6 Filter Heating System. Any heating system capable of maintaining a temperature around the filter holder during sampling of 120 ± 14°C (248 ± 25°F), or such other temperature as specified by an applicable subpart of the standards or approved by the Control Agency's Authorized Representative for a particular application. Alternatively, the tester may opt to operate the equipment at a temperature lower than that specified. A temperature gauge capable of measuring temperature to within 3°C (5.4°F) shall be installed so that the temperature around the filter holder can be regulated and monitored during sampling. Heating systems other than the one shown in APTD-0581 may be used.

2.1.7 Impinger train. The following system shall be used to determine the stack gas moisture content and condensibles: Four impingers connected in series with leak-free ground glass fittings or any similar leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with 1.3 cm (1/2 in) ID glass tube extending to about 1.3 cm (1/2 in) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the impinger train) may be used, subject to the approval of the Control Agency's Authorized Representative. The first and second impingers shall contain known quantities of water (Section 4.1.3), the third shall be empty, and the fourth shall contain a known weight of silica gel, or equivalent desiccant. A thermometer, capable of measuring temperature to within 1°C (2°F) shall be placed at the outlet of the fourth impinger for monitoring purposes.

Alternatively, any system that cools the sample gas stream and allows measurement of the water condensed and moisture leaving the impinger train, each to within 1 ml or 1 g may be used, subject to the approval of the Control Agency' ls Authorized Representative. Acceptable means are to measure the condensed water either gravimetrical or volumetrically and to measure the moisture leaving the impinger train by: (l) monitoring the temperature and pressure at the exit of the impinger train and using Dalton's law of partial pressures; or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap with exit gases kept below 2O°C (68°F) and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the impinger train, it is recommended that silica gel (or equivalent) still be used between the impinger system and pump to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.8 Metering System. Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3°C (5.4°F), dry gas meter capable of measuring volume to within 2 percent, and related equipment, as shown in Figure 5-1.

Other metering systems capable of maintaining sampling rates within 10 percent of isokinetic and of determining sample volumes to within 2 percent may be used, subject to the approval of the Control Agency's Authorized Representative. When the metering system is used in conjunction with a pitot tube, the system shall enable checks of isokinetic rates.

Sampling trains utilizing metering systems designed for higher flow rates than that described in APTD-0581 or APTD-0576 may be used provided that the specifications of this method are met.

2.1.9 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in Hg). In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.10 Gas Density Determination Equipment. Temperature sensor and pressure gauge, as described in Sections 2.3 and 2.4 of Method 2, and gas analyzer, if necessary, as described in Method 3. The temperature sensor shall, preferably, be permanently attached to the pitot tube or sampling probe in a fixed configuration, such that the tip of the sensor extends beyond the leading edge of the probe sheath and does not touch any metal. Alternatively, the sensor may be attached just prior to use in the field. Note, however, that if the temperature sensor is attached in the field, the sensor must be placed in an interference-free arrangement with respect to the Type S pitot tube openings (see Method 2, Figure 2-7). As a second alternative, if a difference of not more than 1 percent in the average velocity measurement is to be introduced, the temperature gauge need not be attached to the probe or pitot tube. (This alternative is subject to the approval of the Control Agency's Authorized Representative.)

2.2 Sample Recovery. The following items are needed:

2.2.1 Probe-Liner and Probe-Nozzle Brushes. Nylon bristle brushes with stainless steel wire handles. The probe brush shall have extensions (at least as long as the probe) of stainless steel, Nylon, Teflon, or similarly inert material. The brushes shall be properly sized and shaped to brush out the probe liner and nozzle.

2.2.2 Wash Bottles - Two. Glass wash bottles are recommended; polyethylene wash bottles may be used at the option of the tester. It is recommended that acetone not be stored in polyethylene bottles for longer than a month.

2.2.3 Glass Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for acetone washes, 500 ml or 1000 ml. Screw cap liners shall either be rubber-backed Teflon or shall be constructed so as to be leak-free and resistant to chemical attack by acetone. (Narrow mouth glass bottles have been found to be less prone to leakage.) Alternatively, polyethylene bottles may be used.

2.2.4 Petri Dishes. For filter samples, glass or polyethylene, unless otherwise specified by the Control Agency's Authorized Representative.

2.2.5 Graduated Cylinder and/or Balance. To measure condensed water to within 1 ml or 1 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Any of these balances are suitable for use here and in Section 2.3.4.

2.2.6 Plastic Storage Containers. Air-tight containers to store silica gel.

2.2.7 Funnel and Rubber Policeman. To aid in transfer of silica gel to container; not necessary if silica gel is weighed in the field.

2.2.8 Funnel. Glass or polyethylene, to aid in sample recovery.

2.3 Analysis. For analysis, the following equipment is needed.

2.3.1 Glass Weighing Dishes.

2.3.2 Desiccator

2.3.3 Analytical Balance. To measure to within 0.1 mg.

2.3.4 Balance. To measure to within 0.5 g.

2.3.5 Beakers. 250 ml.

2.3.6 Hygrometer. To measure the relative humidity of the laboratory environment.

2.3.7 Temperature Gauge. To measure the temperature of the laboratory environment.

3. Reagents

3.1 Sampling. The reagents used in sampling are as follows:

3.1.1 Filters. glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (≤0.05 percent penetration) on 0.3-micron dioctyl phthalate smoke particles. The filter efficiency test shall be conducted in accordance with ASTM standard method D2986-71. Test data from the supplier's quality control program are sufficient for this purpose.

3.1.2 Silica Gel. Indicating type, 6 to 16 mesh. If previously used, dry at 175°C (350°F) for 2 hours. New silica gel may be used as received. Alternatively, other types of desiccants (equivalent or better) may be used, subject to the approval of the Control Agency's Authorized Representative.

3.1.3 Water. When analysis of the material caught in the impingers is required, distilled water shall be used. Run blanks prior to field use to eliminate a high blank on test samples.

3.1.4 Crushed Ice.

3.1.5 Stopcock Grease. Acetone-insoluble, heat-stable silicone grease. This is not necessary if screw-on connectors with Teflon sleeves, or similar, are used. Alternatively, other types of stopcock grease may be used, subject to the approval of the Control Agency's Authorized Representative.

3.2 Sample Recovery. Acetone - reagent grade, ≤0.001 percent residue, in glass bottles - is required. Acetone from metal containers generally has a high residue blank and should not be used. Sometimes, suppliers transfer acetone to glass bottles from metal containers; thus, acetone blanks shall be run prior to field use and only acetone with low values (≤0.001 percent) shall be used. In no case shall a blank value of greater than 0.001 percent of the weight of acetone used be subtracted from the sample weight.

3.3 Analysis. Two reagents are required for the analysis:

3.3.1 Acetone. Same as 3.2.

3.3.2 Desiccant. Anhydrous calcium sulfate, indicating type. Alternatively, other types of desiccants may be used, subject to the approval of the Control Agency's Authorized Representative.

4. Procedure

4.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testors should be trained and experienced with the test procedures.

4.1.1 Pretest Preparation. All the components shall be maintained and calibrated according to the procedure described in APTD-0576, unless otherwise specified herein.

Weigh several 200 to 300 g portions of silica gel in air-tight containers to the nearest 0.5 g. Record the total weight of the silica gel plus container, on each container. As an alternative, the silica gel need not be preweighed, but may be weighed directly in its impinger or sampling holder just prior to train assembly.

Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper diameter on the back side near the edge using numbering machine ink. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccate the filters at 20 ± 5.6°C (68 ± 10°F) and ambient pressure for at least 24 hours and weigh at intervals of at least 6 hours to a constant weight, i.e., 0.5 mg change from previous weighing; record results to the nearest 0.1 mg. During each weighing the filter must not be exposed to the laboratory atmosphere for a period greater than 2 minutes and a relative humidity above 50 percent. Alternatively, (unless otherwise specified by the Control Agency's Authorized Representative), the filters may be oven dried at 105°C (220°F) for 2 to 3 hours, desiccated for 2 hours, and weighed. Procedures other than those described, which account for relative humidity effects, may be used, subject to the approval of the Control Agency's Authorized Representative.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number of sampling points according to Method 1 or as specified by the Control Agency's Authorized Representative. Determine the stack pressure, temperature, and the range of velocity heads using Method 2; it is recommended that a leak-check of the pitot lines (see Method 2, Section 3.1) be performed. Determine the moisture content using Approximation Method 4 or its alternative for the purpose of making isokinetic sampling rate settings. Determine the stack gas dry molecular weight, as described in Method 2, Section 3.6; if integrated Method 3 sampling is used for molecular weight determination, the integrated bag sample shall be taken simultaneously with, and for the same total length of time as, the particulate sample run.

Select a nozzle size based on the range of velocity heads, such that it is not necessary to change the nozzle size in order to maintain isokinetic sampling rates. During the run, do not change the nozzle size. Ensure that the proper differential pressure gauge is chosen for the range of velocity heads encountered (see Section 2.2 of Method 2).

Select a suitable probe liner and probe length such that all traverse points can be sampled. For large stacks, consider sampling from opposite sides of the stack to reduce the length of probes.

Select a total sampling time greater than or equal to the minimum total sampling time specified in the test procedures for the specific industry such that (1) the sampling time per point is not less than 2 min. (or some greater time interval as specified by the Control Agency's Authorized Representative), and (2) the sample volume taken (corrected to standard conditions) will exceed the required minimum total gas sample volume. The latter is based on an approximately average sampling rate.

It is recommended that the number of minutes sampled at each point be an integer or an integer plus one-half minute, in order to avoid timekeeping errors. The sampling time at each point shall be the same.

In some circumstances, e.g., batch cycles, it may be necessary to sample for shorter times at the traverse points and to obtain smaller gas sample volumes. In these cases, the Control Agency's Authorized Representative's approval must first be obtained.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

Place 100 ml of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.5 g and recorded.

Using a tweezer or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as to prevent the sample gas stream from circumventing the filter. Check the filter for tears after assembly is completed.

When glass liners are used, install the selected nozzle using a Viton A O-ring when stack temperatures are less than 260°C (500°F) and an asbestos string gasket when temperatures are higher. See APTD-0576 for details. Other connecting systems using either 316 stainless steel or Teflon ferrules may be used. When metal liners are used, install the nozzle as above or by a leak-free direct mechanical connection. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

Set up the train as in Figure 5-1, using (if necessary) a very light coat of silicone grease on all ground glass joints, greasing only the outer portion (see APTD-0576) to avoid possibility of contamination by the silicone grease. Subject to the approval of the Control Agency's authorized Representative, a glass cyclone may be used between the probe and filter holder when the total particulate catch is expected to exceed 100 mg or when water droplets are present in the stack gas.

Place crushed ice around the impingers.

4.1.4 Leak-Check Procedures.

4.1.4.1 Pretest Leak-Check. A pretest leak-check is required. The following procedure shall be used.

After the sampling train has been assembled, turn on and set the filter and probe heating systems at the desired operating temperatures. Allow time for the temperatures to stabilize. If a Viton A O-ring or other leak-free connection is used in assembling the probe nozzle to the probe liner, leak-check the train at the sampling site by plugging the nozzle and pulling a 380 mm Hg (15 in Hg) vacuum.

Note: A lower vacuum may be used, provided that it is not exceeded during the test.

If an asbestos string is used, do not connect the probe to the train during the leak-check. Instead, leak-check the train by first plugging the inlet to the filter holder (cyclone, if applicable) and pulling a 380 mm Hg (15 in. Hg) vacuum (see Note immediately above). Then connect the probe to the train and leak-check at about 25 mm Hg (1 in Hg) vacuum; alternatively, the probe may be leak-checked with the rest of the sampling train, in one step, at 380 mm Hg (15 in Hg) vacuum. Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable.

The following leak-check instructions for the sampling train described in APTD-0576 and APTD-0581 may be helpful. Start the pump with bypass valve fully open and coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of bypass valve; this will cause water to back up into the filter holder. If the desired vacuum is exceeded, either leak-check at this higher vacuum or end the leak-check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe, filter holder, or cyclone (if applicable) and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced backward into the filter holder and silica gel from being entrained backward into the third impinger.

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) change becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be no greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable and no correction will need to be applied to the total volume of dry gas metered; if, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and plan to correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run. Immediately after component changes, leak-checks are optional; if such leak-checks are done, the procedure outlined in Section 4.14.1 above shall be used.

4.1.4.3 Post-test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leak-check shall be done in accordance with the procedures outlined in Section 4.1.4.1, except that it shall be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be not greater than 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction need be applied to the total volume of dry gas metered. If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

4.1.5 Particulate Train Operation. During the sampling run, maintain an isokinetic sampling rate (within 10 percent of true isokinetic unless otherwise specified by the Control Agency's Authorized Representative) and a temperature around the filter of 120 ± 14°C (248 ± 25°F), or such other temperature as specified by an applicable subpart of the standards or approved by the Control Agency's Authorized Representative.

For each run, record the data required on a data sheet such as the one shown in Figure 5-2. Be sure to record the initial dry gas meter reading. Record the dry gas meter readings at the beginning and end of each sampling time increment, when changes in flow rates are made, before and after each leak-check, and when sampling is halted. Take other readings required by Figure 5-2 at least once at each sample point during each time increment and additional readings when significant changes (20 percent variation in velocity head readings) necessitate additional adjustments in flow rate. Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse.

Clean the portholes prior to the test run to minimize the chance of sampling deposited material. To begin sampling, remove the nozzle cap, verify that the filter and probe heating systems are up to temperature, and that the pitot tube and probe are properly positioned. Position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. (Note: During the period before sampling begins point the nozzle downstream. Rotate the nozzle upstream immediately before the sampling pump is turned on.) Nomographs are available, which aid in the rapid adjustment of the isokinetic sampling rate without excessive computations. These nomographs are designed for use when the Type S pitot tube coefficient is 0.85 ± 0.02, and the stack gas equivalent density (dry molecular weight) is equal to 29 ± 4. APTD-0576 details the procedure for using the nomographs. If C_p and M_d are outside the above stated ranges do not use the nomographs unless appropriate steps are taken to compensate for the deviations. (See Citation 7 in Section 7.)

When the stack is under significant negative pressure (height of impinger stem), take care to close the coarse adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

When the probe is in position, block off the openings around the probe and porthole to prevent unrepresentative dilution of the gas stream.

Traverse the stack cross-section, as required by Method 1 or as specified by the Control Agency's Authorized Representative, being careful not to bump the probe nozzle into the stack walls when sampling near the walls or when removing or inserting the probe through the portholes; this minimizes the chance of extracting deposited material.

During the test run, make periodic adjustments to keep the temperature around the filter holder at the proper level; add more ice and, if necessary, salt to maintain a temperature less than 20°C (68°F) at the condenser/silica gel outlet. Also, periodically check the level and zero of the manometer.

If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sample run. It is recommended that another complete filter assembly be used rather than attepting to change the filter itself. Before a new filter assembly is installed, conduct a leak-check (see Section 4.1.4.2). The total particulate weight shall include the summation of all filter assembly catches.

A single train shall be used for the entire sample run, except in cases where simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or, in cases where equipment failure necessitates a change of trains. In all other situations, the use of two or more trains will be subject to the approval of the Control Agency's Authorized Representative.

Note that when two or more trains are used, separate analyses of the front-half and (if applicable) impinger catches from each train shall be performed, unless identical nozzle sizes were used on all trains, in which case, the front-half catches from the individual trains may be combined (as may the impinger catches) and one analysis of front-half catch and one analysis of impinger catch may be performed. Consult with the Control Agency's Authorized Representative for details concerning the calculation of results when two or more trains are used.

At the end of the sample run, turn off the coarse adjust valve, remove the probe and nozzle from the stack, turn off the pump, record the final dry gas meter reading, and conduct a post-test leak-check, as outlined in Section 4.1.4.3. Also, leak-check the pitot lines as described in Method 2, Section 3.1; the lines must pass this leak-check, in order to validate the velocity head data.

4.1.6 Calculation of Percent Isokinetic. Calculate percent isokinetic (see Calculations, Section 6) to determine whether the run was valid or another test run should be made. If there was difficulty in maintaining isokinetic rates due to source conditions, consult with the Control Agency's Authorized Representative for possible variance on the isokinetic rates.

4.2 Sample Recovery. Proper cleanup procedure begins as soon as the probe is removed from the stack at the end of the sampling period. Allow the probe to cool.

When the probe can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, thus drawing water from the impingers into the filter holder.

Before moving the sample train to the cleanup site, remove the probe from the sample train, wipe off the silicone grease, and cap the open outlet of the probe. Be careful not to loose any condensate that might be present. Wipe off the silicone grease from the filter inlet where the probe was fastened and cap it. Remove the umbilical cord from the last impinger and cap the impinger. If a flexible line is used between the first impinger or condenser and the filter holder, disconnect the line at the filter holder and let any condensed water or liquid drain into the impingers or condenser. After wiping off the silicone grease, cap off the filter holder outlet and impinger inlet. Either ground-glass stoppers, plastic caps, or serum caps may he used to close these openings.

Transfer the probe and filter-impinger assembly to the cleanup area. This area should be clean and protected from the wind so that the chances of contaminating or losing the sample will be minimized.

Save a portion of the acetone used for cleanup as a blank Take 200 ml of this acetone directly from the wash bottle being used and place it in a glass sample container labeled "acetone blank."

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

Container No. 1. Carefully remove the filter from the filter holder and place it in its identified petri dish container. Use a pair of tweezers and/ or clean disposable surgical gloves to handle the filter. If it is necessary to fold the filter, do so such that the particulate cake is inside the fold. Carefully transfer to the petri dish any particulate matter and/or filter fibers which adhere to the filter holder gasket, by using a dry nylon bristle brush and/or a sharp-edged blade. Seal the container.

Container. No. 2. Taking care to see that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover particulate matter or any condensate from the probe nozzle, probe fitting, probe liner, and from half of the filter holder by washing these components with acetone and placing the wash in a glass container. Distilled water may be used instead of acetone when approved by the Control Agency's Authorized Representative and shall be used when specified by the Control Agency's Authorized Representative; in these cases save a water blank and follow the Control Agency's Authorized Representative's directions on analysis. Perform the acetone rinses as follows:

Carefully remove the probe nozzle and clean the inside surface by rinsing with acetone from a wash bottle and brushing with a nylon bristle brush. Brush until the acetone rinse shows no visible particles, after which make a final rinse of the inside surface with acetone. Brush and rinse the inside parts of the Swagelok fitting with acetone in a similar way until no visible particles remain.

Rinse the probe liner with acetone by tilting and rotating the probe while squirting acetone into its upper end so that all inside surfaces will be wetted with acetone. Let the acetone drain from the lower end into the sample container. A funnel (glass or polyethylene) may be used to aid in transferring liquid washes to the container. Follow the acetone rinse with a probe brush. Hold the probe in an inclined position, squirt acetone into the upper end as the probe brush is being pushed with a twisting action through the probe; hold a sample container underneath the lower end of the probe, and catch any acetone and particulate matter which is brushed from the probe. Run the brush through the probe three times or more until no visible particulate matter is carried out with the acetone or until none remains in the probe liner on visual inspection. With stainless steel or other metal probes, run the brush through in the above prescribed manner at least six times since metal probes have small crevices in which particulate matter can be entrapped. Rinse the brush with acetone, and quantitatively collect these washings in the sample container. After the brushing, make a final acetone rinse of the probe as described above.

It is recommended that two people be used to clean the probe to minimize sample losses. Between sampling runs, keep brushes clean and protected from contamination.

After ensuring that all joints have been wiped clean of silicone grease, clean the inside of the front half of the filter holder by rubbing the surfaces with a nylon bristle brush and rinsing with acetone. Rinse each surface three times or more if needed to remove visible particulate. Make a final rinse of the brush and filter holder. Carefully rinse out the glass cyclone, also (if applicable). After all acetone washings and particulate matter have been collected in the sample container, tighten the lid on the sample container so that acetone will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether or not leakage occurred during transport. Label the container to clearly identify its contents.

Container No. 3. Note the color of the indicating silica gel to determine if it has been completely spent and make a notation of its condition. Transfer the silica gel from the fourth impinger to its original container and seal. A funnel may make it easier to pour the silica gel without spilling. A rubber policeman may be used as an aid in removing the silica gel from the impinger. It is not necessary to remove the small amount of dust particles that may adhere to the impinger wall and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, follow the procedure for container No. 3 in Section 4.3.

Impinger Water. Treat the impingers as follows: Make a notation of any color or film in the liquid catch. Measure the liquid which is in the first three impingers to within ± 1 ml by using a graduated cylinder or by weighing it to within ± 0.5 g by using a balance (if one is available). Record the volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas. (See note, Section 2.1.7.)

If a different type of condenser is used, measure the amount of moisture condensed either volumetrically or gravimetrically. Whenever possible, containers should be shipped in such a way that they remain upright at all times.

4.2.1 Determination of the Particulate Concentration. The particulate matter concentration is determined by isokinetically aspirating a measured volume of the stack gas, catching the particulate in a filter, in the probe, connecting tubing, and in the impingers, and dividing the weight of the particulate catch by the volume of gas.

For the APCD rules, matter that is liquid at standard temperature must be included. This liquid matter is assumed to pass as a gas through the filter and to then condense in the impinger water. The weight of this liquid particulate is determined by solvent extraction using methylene chloride followed by an aqueous phase extraction. Caution must therefore be used not to let any acetone or other non-water rinse enter the impinger water.

For the APCD rules, the combined weight of the particulate matter caught in the probe, the filter and the impingers is used in the determination of particulate matter concentration. For some rules only the combined weight of the particulate matter caught in the probe and filter is used in the determination. Accordingly, it is advisable to report the weight of the impinger catch separately so that both the APCD and the ARB determinations can be made. The total particulate matter catch may be itemized by weight as follows: (1) Filter Catch, (2) Probe Catch, (3) Impinger Catch, and (4) Solvent Extract.

4.3 Analysis. Record the data required on a sheet such as the one shown in Figure 5-3. Handle each sample container as follows:

Container No. 1. Leave the contents in the shipping container or transfer the filter and any loose particulate from the sample container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this Section, 4.3, the term "constant weight" means a difference of no more than

0.5 mg or 1 percent of total weight less tare weight, whichever is greater, between two consecutive weighings, with no less than 6 hours of desiccation time between weighings.

Alternatively, the sample may be oven dried at 105°C (220°F) for 2 to 3 hours, cooled in the desiccator, and weighted to a constant weight, unless otherwise specified by the Control Agency's Authorized Representative. The tester may also opt to oven dry the sample at 105°C (220°F) for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

Container No. 2. Note the level of liquid in the container and confirm on the analysis sheet whether or not leakage occurred during transport. If a noticeable amount of leakage has occurred, either void the sample or use methods, subject to the approval of the Control Agency's Authorized Representative, to correct the final results. Measure the liquid in this container either volumetrically to ± 1 ml or gravimetrically to ± 0.5 g. Transfer the contents to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Container No. 3. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g using a balance. This step may be conducted in the field.

"Acetone Blank" Container. Measure acetone in this container either volumetrically or gravimetrically. Transfer the acetone to a tared 250-ml beaker and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 mg.

Note - At the option of the tester, the contents of Container No. 2 as well as the acetone blank container may be evaporated at temperatures higher than ambient. If the evaporation is done at an elevated temperature, the temperature must be below the boiling point of the solvent; also, to prevent "bumping," the evaporation process must be closely supervised, and the contents of the beaker must be swirled occasionally to maintain an even temperature. Use extreme care, as acetone is highly flammable and has a low flash point.

4.3.1 Impinger Catch and Extract

4.3.1.1 The impinger catch consists of the water and organic solvent* rinsings from the sample train connections between the filter and impingers, plus the impinger contents. These are usually received in 1 to 4 one pint wide-mouth Mason jars.

Methylene Chloride (CH_2C1_2) unless the source being evaluated dictates otherwise, then usually benzene is used.

The methylene chloride used in the extraction shall also have a blank run on it, similar to those run for the water and acetone. The methylene chloride extraction is to be corrected the same way the acetone rinse is. The impinger catch extract and impinger catch are to .be weighed to a constant weight as defined earlier.

4.3.1.2 Combine the catch in separatory funnel of suitable size. The Mason jar is to be rinsed with methylene chloride into the separatory funnel.

4.3.1.3 Extract the aqueous catch three times with 50 ml portions of methylene chloride (CH_2Cl_2). Each time, extract for 30 seconds with vigorous shaking, then allow the layers to separate (which may sometimes take up to 15 minutes due to emulsion formation). Drain the CH_2Cl_2 layers into a beaker of suitable size through a short stem funnel containing a cotton plug, to remove droplets of water from the CH_2 C12 extract. Save an aqueous layer for use in Section 4.3.1.8.

4.3.1.4 Rinse the funnel and cotton with fresh CH_2Cl_2 and concentrate the combined CH_2Cl_2 extract to about 25 ml under a stream of clean filtered air at room temperature in a hood.

4.3.1.5 Quantitatively transfer the concentrated extract to a tared 50 ml beaker and evaporate to dryness under the above conditions and place in a desiccator for one hour.

4.3.1.6 Weigh the extract residue to the nearest 0.1 mg.

4.3.1.7 Record the gross and tare weights and report the net weight as "impinger Catch Extract."

4.3.1.8 From Section 4.3.1.3 quantitatively transfer the aqueous phase to a suitable size beaker and concentrate to about 25 ml on a hot plate or steam bath with the aid of the clean filtered air stream.

4.3.1.9 Quantitatively transfer the aqueous concentrate to a rated 50 ml beaker and evaporate to dryness on a steam bath.

4.3.1.10 Place the beaker containing the residue in a 105°C oven for one hour and then let cool in a desiccator.

4.3.1.11 Weigh the residue to the nearest 0.1 mg.

4.3.1.12 Record the gross and tare weights and report the net weight as "Impinger Catch."

4.4 Quality Control Procedures.

The following quality control procedures are suggested to check the volume metering system calibration values at the field test site prior to sample collection. These procedures are optional for the tester.

4.4.1 Meter Orifice Check. Using the calibration data obtained during the calibration procedure described in Section 5.3, determine the H for the metering system orifice. The ΔH@ is the orifice pressure differential in units of in H_2O that correlates to 0.75 cfm of air at 528°R and 29.92 in Hg. The ΔH@ is calculated as follows:

$$\Delta H@ = 0.0319\ \Delta H\ \frac{T_m}{P_{bar}}\ \frac{\theta}{Y^2 V_m^2} \qquad \text{Eq. 5-9}$$

Where:

ΔH@= Average pressure differential across the orifice meter, in H_2O.

T_m = Absolute average dry gas meter temperature, 0R.

P_{bar} = Barometric pressure, in Hg.

θ = Total sampling time, min.

Y = Dry gas meter calibration factor, dimensionless.

V_m = Volume of gas sample as measured by dry gas meter, dcf.

0.0319 = (0.0567 in Hg/°R) x $(0.75\ \text{cfm})^2$

Before beginning the field test (a set of three runs usually constitutes a test), operate the metering system (i.e., pump, volume meter, and orifice) at the ΔH@ pressure differential for 10 minutes. Record the volume collected, the dry gas meter temperature and the barometric pressure.

Calculate a dry gas meter calibration check value, Y_c as follows:

$$Y_c = \frac{10}{V_m}\left[\frac{0.0319\ T_m}{P_{bar}}\right]^{1/2} \qquad \text{Eq. 5-10}$$

Where:

Y_c = Dry gas meter calibration check value, dimensionless.

10 = 10 minutes of run time.

Compare the Y_c value with the dry gas meter calibration factor Y to determine that: $0.97Y < Y_c > 1.03Y$.

If the Y_c value is not within this range, the volume metering system should be investigated before beginning the test.

4.4.2 Calibrated Critical Orifice. A calibrated critical orifice, calibrated against a wet test meter or spirometer and designed to be inserted at the inlet of the sampling meter box, may be used as a quality control check, such procedure being subject to approval by Control Agency's Authorized Representative.

5. Calibration

Maintain a laboratory log of all calibrations.

5.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of nozzle to the nearest 0.025 mm (0.01 in). Make three separate measurements using different diameters each time, and obtain the average of the measurements. The difference between the high and low numbers shall not exceed 0.1 mm (0.004 in). When nozzles become nicked, dented, or corroded, they shall be reshaped, sharpened, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

5.2 Pitot Tube. The Type S pitot tube assembly shall be calibrated according to the procedure outlined in Section 4 of Method 2.

5.3 Metering System. Before its initial use in the field, the metering system shall be calibrated according to the procedure outlined in APTD-0576. Instead of physically adjusting the dry gas meter dial readings to correspond to the wet test meter readings, calibration factors may be used to mathematically correct the gas meter dial readings to the proper values. Before calibrating the metering system, it is suggested that a leak-check be conducted. For metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057 m^3/min (0.02 cfm); at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divide the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m^3/min (0.02 cfm).

After each field use, the calibration of the metering systems shall be checked by performing three calibration runs at a single, intermediate orifice setting (based on the previous field test), with the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the metering system. Calculate the average value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the full range of orifice settings, as outlined in APTD-0576.

Alternative procedures, e.g., using the orifice meter coefficients, may be used, subject to the approval of the Control Agency's Authorized Representative.

Note - If the dry gas meter coefficient values obtained before and after a test series differ by more then 5 percent, the test series shall either be voided, or calculations for the test series shall be performed using whichever meter coefficient value (i.e., before or after) gives the lower value of total sample volume.

5.3.1 Calibration Prior to Use. Before its initial use in the field, the metering system shall be calibrated as follows: Connect the metering system inlet to the outlet of a wet test meter that is accurate to within 1 percent. Refer to Figure 5.5. The wet test meter should have a capacity of 30 liters/rev (1 ft^3/rev). A spirometer of 400 liters (14 ft^3) or more capacity or equivalent may be used for this calibration, although- a wet test meter is usually more practical. The wet test meter should be periodically calibrated with a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained. Run the metering system pump for about 15 minutes with the orifice manometer indicating a median reading as expected in field use to allow the pump to warm up and to permit the interior surface of the wet test meter to be thoroughly wetted. Then, at each of a minimum of three orifice manometer settings, pass an exact quantity of gas through the wet test meter and note the gas volume indicated by the dry gas meter. Also note the barometric pressure, and the temperatures of the wet test meter, the inlet of the dry gas meter, and the outlet of the dry gas meter. Select the highest and lowest orifice settings to bracket the expected field operating range of the orifice. Use a minimum volume of 0.15 m^3 (5 cf) at all orifice settings. Record all the data on a form similar to Figure 5.6 and calculate Y, the dry gas meter calibration factor, and ΔH@ the orifice calibration factor, at each orifice setting as shown on Figure 5.6. Allowable tolerances for individual Y and ΔH@, values are given in Figure 5.6. Use the average of the Y values in the calculations in Section 6. Before calibrating the metering system, it is suggested that a leak-check be conducted for metering systems having diaphragm pumps, the normal leak-check procedure will not detect leakages within the pump. For these cases the following leak-check procedure is suggested: make a 10-minute calibration run at 0.00057 m^3/min (0.02 cfm): at the end of the run, take the difference of the measured wet test meter and dry gas meter volumes; divide the difference by 10, to get the leak rate. The leak rate should not exceed 0.00057 m^3/min (0.02 cfm).

5.3.2 Calibration After Use. After each field use, the calibration of the metering system shall be checked by performing three calibration runs at a single, intermediate orifice setting (based on the previous field test) with the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the metering system. Calculate the average value of the dry gas meter calibration factor. If the value has changed by more than 5 percent, recalibrate the meter over the full range of orifice settings, as previously detailed.

Alternative procedures e.g., rechecking the orifice meter coefficient may be used, subject to the approval of the Control Agency's Authorized Representative.

5.3.3 Acceptable Variation in Calibration. If the dry gas meter coefficient values obtained before and after a test series differ by more than 5 percent, the test series shall either be voided, or calculations for the test series shall be performed using whichever meter coefficient value (i.e., before or after) gives the lower value of total sample volume.

5.4 Probe Heater Calibration.

The probe heating system shall be calibrated before its initial use in the field. Use a heat source to generate air heated to selected temperatures that approximate those expected to occur in the sources to be sampled. Pass this air through the probe at a typical simple flow rate while measuring the probe inlet and outlet temperatures at various probe heater settings. For each air temperature generated, construct a graph of probe heating system setting versus probe outlet temperature. The procedure outlined in APTD-0576 can also be used. Probes constructed according to APTD-0581 need not be calibrated if the calibration curves in APTD-0576 are used. Also, probes with outlet temperature monitoring capabilities do not require calibration.

5.5 Temperature Gauges.

Use the procedure in section 4.3 of Method 2 to calibrate in-stack temperature gauges. Dial thermometers, such as are used for the dry gas meter and condenser outlet, shall be calibrated against mercury-in-glass thermometers.

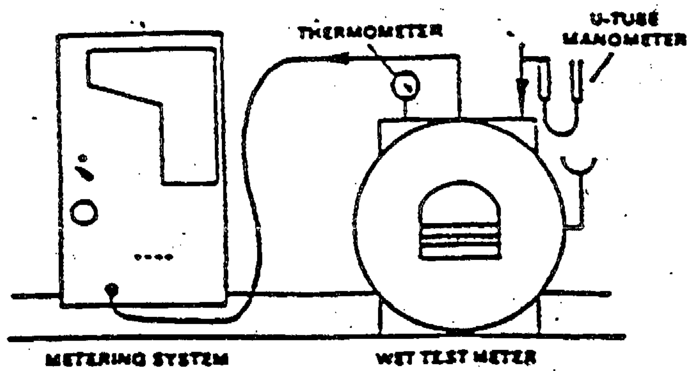

Figure 5.5 Equipment arrangement for metering system calibration.

Date ____________________ Metering System Identification: ____________________

Barometric pressure, P_b = ______ in. Hg

Orifice manometer setting ΔH in. H_2O	Spirometer (wet meter) gas volume (V_w) ft^3	Dry gas meter volume (V_d) ft^3	Temperatures: Spirometer (wet meter) (t_w) °F	Temperatures: Dry Gas Meter: Inlet (t_i) °F	Temperatures: Dry Gas Meter: Outlet (t_o) °F	Temperatures: Dry Gas Meter: Average (t_d) °F	Time (θ) min

Calculations

ΔH in. H_2O	Y: $\dfrac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$	$\Delta H_@$: $\dfrac{0.0317\ \Delta H}{P_b (t_d + 460)} \left[\dfrac{(t_w + 460)\theta}{V_w}\right]^2$
Average		

Y = Ratio of reading of wet test meter to dry test meter; tolerance for individual values ± 0.02 from average.

$\Delta H_@$ = Orifice pressure differential that equates to 0.75 cfm of air @ 68°F and 29.92 inches of mercury, in. H_2O; tolerance for individual values ± 0.20 from average.

Figure 5.6. Example data sheet for calibration of metering system (English units).

5.6 Leak Check of Metering System Shown in Figure 5-1.

That portion of the sampling train from the pump to the orifice meter should be leak-checked prior to initial use and after each shipment. Leakage after the pump will result in less volume being recorded than is actually sampled. The following procedure is suggested (see Figure 5-4): Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing attached into the orifice exhaust pipe. Disconnect and vent the low side of the orifice manometer. Close off the low side orifice tap. Pressurize the system to 13 to 18 cm (5 to 7 in) water column by blowing into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box; leaks, if present, must be corrected.

5.7 Barometer. Calibrate against a mercury barometer.

6. Calculations

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

6.1 Nomenclature

A_n = Cross-sectional area of nozzle, m^2 (ft^2).

B_{ws} = Water vapor in the gas stream, proportion by volume.

C_a = Acetone blank residue concentrations, mg/g.

C_s = Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/dscm (g/dscf).

I = Percent of isokinetic sampling.

L_a = Maximum acceptable leakage rate for either a pretest leak-check or for a leak check following a competent change; equal to 0.00057 m^3/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.

L_i = Individual leakage rate observed during the leak-check conducted prior to the "ith" component change (i = 1, 2, 3, ...n), m^3/min (cfm).

L_p = Leakage rate observed during the post-test leak check m^3/min (cfm).

m_n = Total amount of particulate matter collected, mg.

M = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

m_a = Mass of residue of acetone after evaporation, mg.

P_{bar} = Barometric pressure at the sampling site, mm Hg (in Hg).

P_s = Absolute stack gas pressure, mm Hg (in Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in Hg).

R = Ideal gas constant 0.06236 mm Hg-m^3/°K-g-mole (21.85 in Hg-ft^3/°R-lb-mole).

T_m = Absolute average dry gas meter temperature (see Figure 5-2), °K (°R). Note: T_m will depend on type of meter used and sampling configuration.

T_s = Absolute average stack gas temperature (see Figure 5-2), ^{0}K (^{0}R).

T_{std} = Standard absolute temperature, 293°K (528°R).

V_a = Volume of acetone blank, ml.

V_{aw} = Volume of acetone used in wash, ml.

V_{lc} = Total volume of liquid collected in impingers and silica gel (see Figure 5-3), ml.

V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).

$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{w(std)}$ = Volume of water vapor in the gas sample, corrected to standard conditions, scm (scf).

V_s = Stack gas velocity, calculated by Method 2, Equation 2-9, using data obtained from Method 5, m/sec (ft/sec).

W_a = Weight of residue in acetone wash, mg.

Y = Dry gas meter calibration factor.

ΔH = Average pressure differential across the orifice meter (see Figure 5-2), mm H_20 (in H_20).

P_a = Density of acetone, mg/ml (see label on bottle).

P_w = Density of water, 0. 9982 g/ml (0.002201 1 b/ml).

θ = Total sampling time, min.

θ_1 = Sampling time interval, from the beginning of a run until the first component change, min.

θ_i = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.

θ_p = Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, min.

13.6 = Specific gravity of mercury.

60 = Sec/min.

100 = Conversion to percent.

6.2 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Figure 5-2).

6.3 Dry Gas Volume. Correct the sample volume measured by the dry gas meter to standard conditions (20°C, 760 mm Hg or 68°F, 29.92 in Hg) by using

$$V_{m(std)} = V_m Y \left(\frac{T_{std}}{T_m}\right) \left[\frac{P_{bar} + \Delta H/13.6}{P_{std}}\right] = K_1 V_m Y \frac{P_{bar} + (\Delta H/13.6)}{T_m}$$

Equation 5-1

where:

$$K_1 = \frac{T_{std}}{P_{std}} = 0.3858°K/mm\ Hg \text{ for metric units.}$$

$= 17.65°R/in\ Hg$ for English units.

Note: Equation 5-1 can be used as written unless the leakage rate observed during any of the mandatory leak-checks (i.e., the post-test leak-check or leak-checks conducted prior to component changes) exceeds L_a. If L_p or L_i exceeds L_a, Equation 5-1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace V_m in Equation 5-1 by the expression:

$$V_m - (L_p - L_a)\theta$$

(b) Case II. One or more component changes made during sampling run. In this case, replace V_m in Equation 5-1 by the expression:

$$V_m - (L_i - L_a)\theta_1 - \sum_{i=2}^{n} (L_i - L_a)\theta i - (L_p - L_a)\theta p$$

and substitute only for those leakage rates (L_i or L_p) which exceed L_a.

6.4 Volume of water vapor.

$$V_{w(std)} = V_{lc} \frac{P_w}{M_w} \frac{RT_{std}}{P_{std}} = K_2 V_{lc}$$

Equation 5-2

where:

K2	=	0.001 333 m^3/ml for metric units.
	=	0.04707 ft^3/ml for English units.

6.5 Moisture Content.

$$B_{ws} = \frac{V_{w(std)}}{V_{m(std)} + V_{w(std)}}$$

Equation 5-3

Note: In saturated or water droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one from the impinger analysis (Equation 5-3), and a second from the assumption of saturated conditions. The lower of the two values of B_{ws} shall be considered correct. The procedure for determining the moisture content based upon assumption of saturated conditions is given in the Note of Section 1.2 of Method 4. For the purposes of this method, the average stack gas temperature from Figure 5-2 may be used to make this determination, provided that the accuracy of the in-stack temperature sensor is $\pm 1^{\circ}C$ ($2^{\circ}F$).

6.6 Acetone Blank Concentrations.

$$C_a = \frac{m_a}{V_a P_a}$$

Equation 5-4

6.7 Acetone Wash Blank.

$$W_a = C_a\ V_{aw}\ P_a$$

Equation 5-5

6.8 Total Particulate Weight.

Determine the total particulate catch from the sum of the weights

Location ____________________
Date ____________________
Operator ____________________
Meter Box No. ____________________
Local Time.
Start/Stop ____________________

Pitot Tube Factor ____________________
Probe Tip Dia, in. ____________________
Probe Length ____________________
Sample Train
Leak Test
Before __________ After __________
Pitot Tube
Leak Test
Before __________ After __________

Project No. ____________________
Plant Name ____________________
Ambient Temp °F ____________________
Meter Temp °F ____________________
Bar. Press, "Hg ____________________
Stack Press, "H_2O ____________________
Assumed Moisture, % ____________________
Heater Box Setting, °F ____________________
Probe Heater Setting, °F ____________________

Point	Clock Time	Dry Gas Meter, CF	Pitot in. H_2O ΔP	Orifice ΔH in H_2O		Impinger Temp. °F	Filter Box Temp. °F	Stack Temp. °F	Pump Vacuum in. Hg
				Desired	Actual				
Start									

FIGURE 5.2
PARTICULATE FIELD DATA

obtained from containers 1 and 2 less the acetone blank (see Figure 5-3). Note - Refer to Section 4.1.5 to assist in calculations of results involving two or more filter assemblies or two or more sampling trains.

6.9 Particulate Concentration.

$$C_s = (0.001 \text{ g/mg}) (m_n/V_{m(std)})$$

Equation 5-6

6.10 Conversion Factors:

From	To	Multiply by
scf	m^3	0.02832
g/ft^3	gr/ft^3	15.43
g/ft^3	lb/ft^3	2.205×10^{-3}
g/ft^3	g/m^3	35.31

6.11. Isokinetic Variation.

6.11.1 Calculation From Raw Data.

$$I = \frac{100\ T_s\ [K_3 V_{lc} + (V_m/T_m)\ (P_{bar} + \Delta H/13.6)]}{60\ \theta v_s P_s A_n}$$

Equation 5-7

where:

K3 = 0.003454 mm Hg - m^3/ml - °R for English units

K3 = 0.002669 in Hg - ft^3/ml - °R for English units

6.11.2 Calculation from Intermediate Values

$$I = \frac{T_s V_{m(std)} P_{std}\ 100}{T_{std} V_s\ \theta\ A_n P_s 60\ (1 - B_{ws})}$$

$$= K4\ \frac{T_s V_m(std)}{P_s V_s\ \theta\ A_n \theta\ \ (1 - B_{ws})}$$

Equation 5-8

where

K4 = 4.320 for metric units.

= 0.09450 for English units.

Acceptable Results. If 90 percent < I< 110 percent, the particulate concentration results are acceptable. If there is a high bias to the results, i.e., I < 90 percent, then the results are defined as at or below the determined value, and the Control Agency's Representative may opt to accept the results. If there is a low bias to the results, i.e. I > 110 percent, then the results are defined as at or above the determined value, and the Control Agency's Representative may opt to accept the results. Otherwise reflect the results and repeat the test.

7. Bibliography

Plant ____________________

Date ____________________

Run No. ____________________

Filter No. ____________________

Amount liquid lost during transport ____________________

Acetone blank volume, ml ____________________

Acetone wash volume, ml ____________________

Acetone blank concentration, mg/mg (equation 5-4) ____________________

Acetone wash blank, mg (equation 5-5) ____________________

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED, mg		
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN
1			
2			
TOTAL	X	X	
		Less acetone blank	
		Weight of particulate matter	

	VOLUME OF LIQUID WATER COLLECTED	
	IMPINGER VOLUME, ml	SILICA GEL WEIGHT, g
FINAL		
INITIAL		
LIQUID COLLECTED		
TOTAL VOLUME COLLECTED		g* ml

*CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER (1g/ml).

$$\frac{\text{INCREASE, g}}{1\ \text{g/ml}} = \text{VOLUME WATER, ml}$$

Figure 5-3. Analytical data.

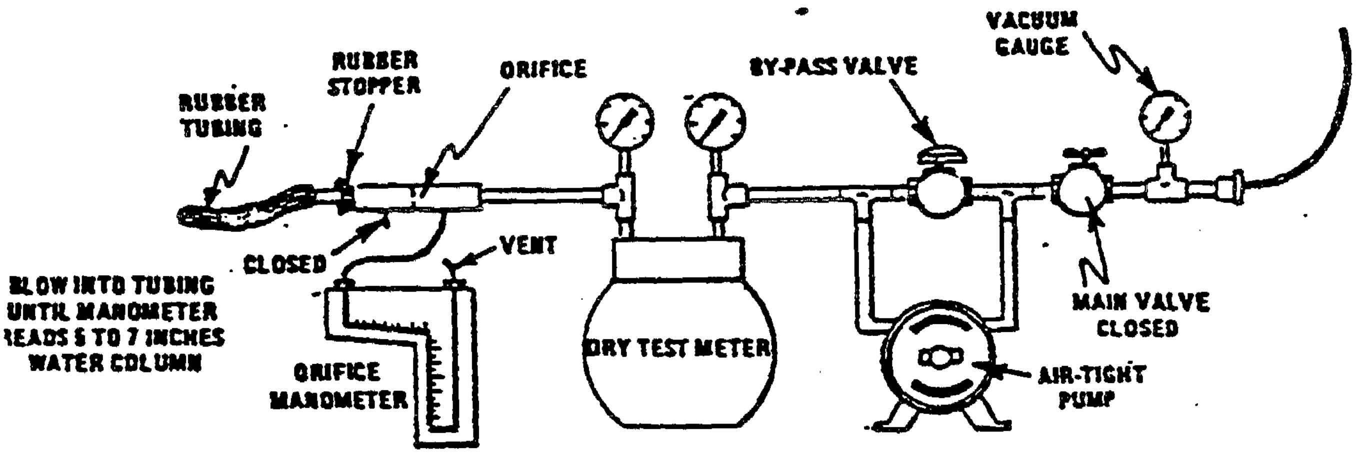

Figure 5-4. Leak check of meter box.

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APPENDIX D

Appendix D contains:

- A Pre-Inspection Worksheet, to be used as a sample for air pollution district inspectors. A sheet like this should be filled out by the inspector before he visits a facility with a baghouse.

- An Inspection Checklist. This 9-step checklist is based on the steps outlined in the chapter on inspections in the Baghouse manual. This checklist is to be used as a sample checklist. Inspectors may wish to draw up their own checksheets.

Pre-Inspection Worksheet

Source ID No. ______________________ SIC ______________________
Inspector(s) ______________________ Date ______________________
Inspection Announced? ______________________

A. General Plant Data from District File

Plant name, address, and phone number ______________________
____
____
____

Name of plant contact, title, and phone number ______________________
____
____

Type of process ______________________
____

Allowable emission rate and opacity ______________________
____
____
____

Date baghouse installation approved ______________________
____
____

Prior complaints or episodes of excess emissions ______________________
____
____
____

Last inspection date ______________________

Purpose of inspection ______________________
____

B. Process Information

Confidential? Yes_____ No_____

Person supplying process information and title ______________________
____

Product(s)____
____

Production rate(s) ____
____

Raw materials used ____
____
____

Portion of process controlled by baghouse ____
____
____
____

Average uncontrolled emission rate or concentration (indicate whether obtained from stack test, mass balance, AP-42 emission factor, other, etc.) ______________________________
____
____

Date of last stack test and average emission rate obtained _________________________
____
____

Is cleaned effluent recirculated back into plant? Yes_____ No_____

D. Dust Characteristics

Is material toxic or otherwise hazardous or does it require special handling?
Yes_____ No_____ Describe____
____

Moisture content or other gaseous constituents ____________________________________
____

Abrasiveness or other properties ____
____

Particle size data - indicate how measured ____
____
____

E. Collection System(s)

Baghouse	#1	#2	#3
Manufacturer			
Type or trade name			
Model No.			
No. of Compartments			
Bags / compartment			
Bag l x d			
Total cloth area			

Fan	#1	#2	#3
Manufacturer			
Model No.			
Blade type			
Belt or direct drive			
Power rating			
Positive or negative pressure			

Fabric	#1	#2	#3
Manufacturer			
Material			
Woven or felted			
Weave			
Weight			
Permeability			
Operating temp. range			
Surface treatment			
Coating upon startup			
Guaranteed life			
Actual life			

Cleaning System	#1	#2	#3
Method			
Frequency			
Actuated by			
Anticollapse rings			
Wire mesh cages			

F. Dust handling system(s)

Type of dust transport system ______________________________

____

Fate of collected material ______________________________

____

Inspection Checklist

This checklist is designed to serve as an example of the information gathering process that a regulatory agency inspector may follow in order to make a compliance determination. District inspectors may wish to use this checklist as a guide in drawing up their own baghouse inspection sheets.

Step 1	Observe the Stack Effluent
Step 2	Check the Continuous Emission Monitors
Step 3	Measure the Fan Operating Parameters
Step 4	Record and Evaluate Baghouse Parameter Monitors
Step 5	Inspect Baghouse Exterior
Step 6	Inspect Dust Capture System
Step 7	Evaluate Process Operating Records
Step 8	Internal Inspection
Step 9	Review of Operating Records

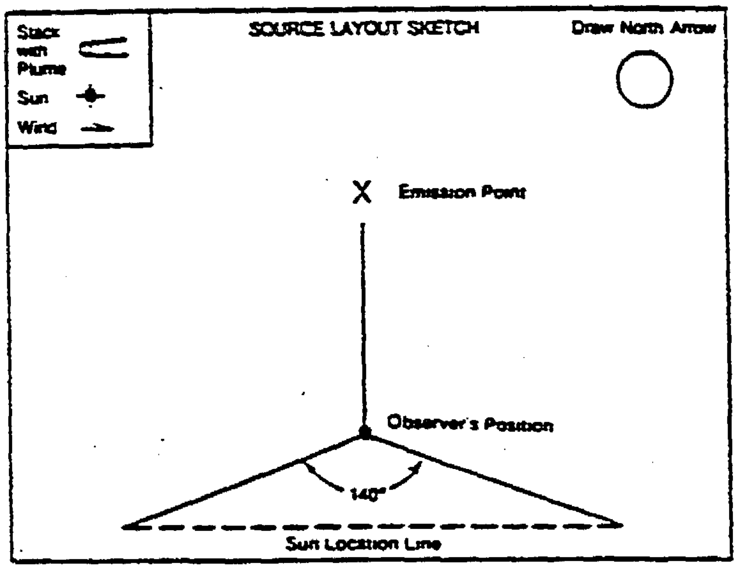
VISIBLE EMISSION OBSERVATION FORM

No.

COMPANY NAME	
STREET ADDRESS	
CITY	STATE / ZIP
PHONE (KEY CONTACT)	SOURCE ID NUMBER
PROCESS EQUIPMENT	OPERATING MODE
CONTROL EQUIPMENT	OPERATING MODE
DESCRIBE EMISSION POINT	
HEIGHT ABOVE GROUND LEVEL	HEIGHT RELATIVE TO OBSERVER Start End
DISTANCE FROM OBSERVER Start End	DIRECTION FROM OBSERVER Start End
DESCRIBE EMISSIONS Start End	
EMISSION COLOR Start End	IF WATER DROPLET PLUME Attached ☐ Detached ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED Start End	
DESCRIBE PLUME BACKGROUND Start End	
BACKGROUND COLOR Start End	SKY CONDITIONS Start End
WIND SPEED Start End	WIND DIRECTION Start End
AMBIENT TEMP Start End	WET BULB TEMP / RH, percent

SOURCE LAYOUT SKETCH

Draw North Arrow



ADDITIONAL INFORMATION	

OBSERVATION DATE	START TIME	END TIME

SEC / MIN	0	15	30	45	COMMENTS
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

OBSERVER'S NAME (PRINT)	
OBSERVER'S SIGNATURE	DATE
ORGANIZATION	
CERTIFIED BY	DATE
CONTINUED ON VEO FORM NUMBER	

Step 2 Check the Continuous Emission Monitors

Opacity monitor readings

Operating: Yes_____ No_____
Minimum, %___________
Average, %___________
Maximum, %___________

Spikes (Characterize frequency, duration, intensity)

____
____
____

Calibration spikes (Characterize levels, frequency)

____
____
____

Calibrated according to required schedule: Yes_____ No_____

Gas temperature

____
____

O_2 inlet level, %: Baseline_____ Present_____
O_2 outlet level, %: Baseline_____ Present_____
Difference in present values greater than 1%? Yes_____ No_____
(If "Yes" inleakage is probably occurring)

CO_2 inlet level, %: Baseline_____ Present_____
CO_2 outlet level, %: Baseline_____ Present_____

Comments

____
____
____
____
____

Step 3 Measure the Fan Operating Parameters

	Parameter	Baseline	Present	Change, %
1.	Increase in total static pressure across fan	______	______	________
2.	Electric current drawn by fan motor	______	______	________
3.	Fan wheel rotation speed (rpm)	______	______	________
4.	Gas temperature at fan inlet	______	______	________
5.	Flue gas oxygen level at fan inlet	______	______	________

A. Baseline and present values of Parameters 1, 2, 3, differ by less than 10%: Yes___ No___

B. Baseline and Present values for Parameter 4 differ by less than 20 °F: Yes___ No___

(If answers to questions A and B are both 'Yes' then mass emissions have probably not changed significantly.)

Mass emissions may have increased significantly: Yes____ No____

(Increased oxygen levels in flue gas indicate air inleakage.)

(Reduced gas temperature and increased electric current indicate air inleakage.)

Air inleakage may be significant: Yes____ No____

Step 4 Record and Evaluate Baghouse Parameter Monitor Readings

	Baseline	Present	Comments
Temperature			
Pressure drop			
Gas volume flow			
Moisture content			
Compressed air pressure			
Reverse air pressure			
Air-to-cloth ratio, gross			
A/C ratio, net (2 compartments off-line)			
Efficiency			
Emission rate			
Opacity			

Step 5 Inspect Baghouse Exterior

Check the following items:

Access doors ______________________________
____

Top access hatches ______________________________
____

Expansion joints ______________________________
____

Ducts ______________________________
____

Condition of exterior housing ______________________________
____
____
____

Look and listen for the following:

- Air inleakage
- Corrosion
- Missing parts
- Unusual odors
- Loose bolts
- Air leakage or fugitive emissions
- Warping
- Unusual noises
- Elevated temperatures

Bag cleaning system:

Air reservoir pressure: Baseline__________ Present__________
Valves actuating: Yes_____ No_____
____
____
____

Compressed air system:
Aftercoolers: Yes_____ No_____
Automatic condensate trap: Yes _____ No_____
Filters: Yes_____ No_____
Water or rust deposits present in system? Yes_____ No_____
Water or other material retained in oil traps, if any? Yes_____ No_____

Step 6 Ash Handling Procedures

Vibrators: Yes_____ No _____
Operating: Yes_____ No_____

Heaters: Yes_____ No_____
Operating: Yes_____ No_____

Level indicators / alarms: Yes_____ No_____
Operating: Yes_____ No_____

Transport equipment: Screws_____ Pneumatic_____ Other_____
Operating: Yes_____ No_____

Evidence of inleakage

____

____

____

Comments

____

____

____

Step 7 Process Operating Conditions

	Baseline or Permitted Values	Present Values
Process weight	____________	____________
Gas flow rate	____________	____________
Excess air	____________	____________
Gas temperature	____________	____________
Pressure drop across baghouse	____________	____________
Moisture content	____________	____________
Flue gas analysis (% O_2, CO_2, ...)	____________	____________
____________________	____________	____________
____________________	____________	____________
____________________	____________	____________

Comments: ____

____

____

____

Step 8 Internal Inspection (Optional)

Internal inspection should be scheduled for a time when plant is shut down.

Caution: Before performing internal inspection, personnel should ensure that all safety measures are observed.

The inspector may be able to peer into a baghouse while it is operating. Permission from the operator must be obtained first. Make sure compartment is isolated.

View from clean-side access hatch:

Clean-side dust deposits? Yes_____ No_____ Comments________________________________

____

____

Poor bag tension? Yes_____ No_____ Comments________________________________

____

View from dirty-side access hatch (use caution!):

Bags being blinded? Yes_____ No_____ Comments________________________________

____

____

Any holes in bags visible? Yes_____ No_____ Comments________________________________

____

____

When conducting a full internal inspection, the following items should also be checked:

Inlet plenum ____

Baffles ____

Solenoid valves ____

Poppet valves ____

Bag clamps ____

Mechanical linkages ____

Thickness of dust layer in bags ____

____

Pinholes in any bags? ____

____

More than 1/4 inch dust layer on floor plates? ________________________________

Bags wearing prematurely? ____

Perform screwdriver rip test on bags removed from service. Results: ______________________

____

____

Step 9 Review Operating Records

Recordkeeping Requirements	Records Kept Satisfactorily
Opacity meter	Yes_____ No_____ Comments__________________
Baghouse inlet gas temperature	Yes_____ No_____ Comments__________________
Baghouse outlet gas temperature	Yes_____ No_____ Comments__________________
Pressure drop across baghouse	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________

Maintenance Logs Kept	Records Kept Satisfactorily
Location of failed bags	Yes_____ No_____ Comments__________________
Bag replacement frequency	Yes_____ No_____ Comments__________________
Cause of bag failure	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________
________________________	Yes_____ No_____ Comments__________________

Percent of time baghouse has been fully operational when process is in operation: ______________

Has a detailed maintenance schedule been instituted? ________________________________

Is maintenance schedule as recomended by baghouse manufacturer or by plant? ______________

How long are records kept on file? ________________________________

Are spare parts kept on hand? ________________________________

Which of the following problem areas have led to periods of excess emissions or caused the process to be shut down?

Problem area	Duration	Frequency
Insufficient dust pickup		
and/or transport (fugitive emissions)		
Duct abrasion or corrosion		
Temperature excursions,		
high or low		
Moisture		
Fan abrasion, vibration, etc.		
Gross bag failure		
Inadequate bag tension		
Bag chafing or abrasion		
Pressure loss		
Compartment isolation dampers		
Cleaning mechanism		
Visible emissions		
Plugged hoppers		
Hopper fires		
Dust discharge system		

If frequent breakdowns have occurred, can the source show maintenance records to demonstrate they have made good faith efforts to treat causes of operating problems?

____

____

____

____

____

____

Conclusions / Recommendation

Compliance status ______________________________

Need for further action ______________________________

Corrective actions to be taken ______________________________

Time required to rectify problems ______________________________

Need for follow-up inspection ______________________________

Inspector's signature	______________
Date	______________
Approved by	______________
Title	______________

APPENDIX E

Appendix E contains troubleshooting guidelines for common baghouse operating problems.

Troubleshooting Guidelines for Common Baghouse Operating Problems [11]

Problem or Symptom	Probable Cause	Remedy
1. Visible discharge/dust in clean air plenum	a. Bags improperly installed	● Check bag installation procedures; repair as necessary.
	b. Bag clamps too loose	● Tighten bag clamps.
	c. Torn or damaged bags	● Replace or tie off and replace at later date.
	d. Leakage at tube sheet (field assembled units)	● Check tube sheet joints; repair as necessary.
	e. Venturi fasteners loose or missing (PJ)	● Repair as necessary
	f. Insufficient filter cake	● Allow more dust to build up on bags by cleaning less frequently. Use a precoat (startup only).
	g. Bags too porous	● Send bag out for permeability test and consult with manufacturer.
	h. Inadequate bag tension	● Check tension and/or springs for compression to proper length.
2. Excessive pressure drop (a differential pressure of 1 to 6 in. W.C. can be considered normal)	a. Gas flow too high	● Check fan speed and damper positions; adjust to specified ratings. Check system design. Check isolation dampers, valves, linkage and seals. Check air supply on pneumatic operators.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	b. Improper bag cleaning action.	● Refer to problem 6.
	c. Improper dust discharge from hopper	● Check seal around slide gate (or in airlock); reseal if leakage is occurring. Ensure continuous dust removal from hoppers.
	d. Moisture blinding of filter bags	● Correct cause of excess moisture and replace bags. Recovery of bag is sometimes possible by running cleaning system (without moving air through collector) from 1 to 30 hours.
	e. Clogging of filter bags	● Eliminate oil or static charges from collector. Control airflow during startup. Check for excessive operating temperature. Check to see that dust characteristics have not changed. If using laundered bags, check for shrinkage.
	f. Static electricity in collector	● Increase relative humidity if possible. Use grounded filter bags.
	g. Excessive dust in clean air plenum (can diminish cleaning effectiveness by plugging the bags in the reverse direction). Damaged or inefficient bags.	● Clean plenum, check bags for dirt on clean side; clean or replace bags.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	h. Insufficient blowring air (RJ)	● Check drive belts on blower, blower speed, blower rotation; replace inlet blower filter; check blowring hose; check blowring for clogged slots.
	i. Nonoperative blowring drive (RJ)	● Check belts on reversing motor; check for broken chains or chain off sprocket; check sheaves or sprockets for loose set screws, check setting of tripper pins; check tripper lever for bend, looseness, or binding.
	j. Incorrect pressure reading	● Clean out pressure taps; check hoses for leaks; check for proper fluid in manometer; check diaphragm in gauge.
3. High bag failure rate		
a. Deterioration/decomposition	a. Improper bag material for dust chemical composition	● Analyze dust and check with manufacturer. Treat with neutralizer prior to collector.
	b. Operating below acid dewpoint	● Increase gas temperature. Bypass collector during startup/shutdown.
b. Wearing out/abrasion	a. Baffle plate worn out	● Replace baffle plate.
	b. Excessive dust loading and/or large abrasive metallic particles	● Install primary collector upstream of baghouse.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	c. Cleaning cycle too frequent (PJ)	● Increase cleaning interval.
	d. Shaking too violent (S)	● Decrease shaking frequency and/or amplitude.
	e. Inlet air not properly baffled from bags	● Consult manufacturer.
	f. Pulse pressure too high (PJ)	● Reduce pressure.
	g. Bag cages have barbs (PJ)	● Remove or smoothe barbs.
c. Burning or accelerated fabric deterioration	a. Stratification of hot and cold gases	● Install baffles to create turbulence.
	b. Sparks entering collector	● Install spark arrestor.
	c. Failure of cooling or dilution system.	● Check design with manufacturer.
	d. Excessive temperature	● Reduce operating temperature or use filter bags of higher temperature rating.
d. Other	a. Hopper bridging	● Material buildup into the bag area can overstress filter elements. Locate cause of bridging and correct; clean out hopper.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
4. Filtering action impaired	a. Improper cleaning system operation.	● Refer to Item 6.
	b. Excessive moisture entering collector blinding bags.	● Refer to item 2.d.
	c. Incorrect gas flow	● Refer to Item 5.
	d. Incorrect bag material for gas composition	● Replace with bags of proper material for type of dust.
	e. Gas temperature higher than specified.	● Refer to Item 3.c.d.
	f. Static electricity buildup in collector	● Refer to Item 2.f.
5. Gas flow through system below design rating/low fan amperage.	a. Incorrect fan speed or direction	● Check rotation, correct if wrong, change sheave ratio.
	b. High differential pressure drop	● Refer to Item 2.
	c. Fan belts slipping	● Check tension on fan belts and adjust if necessary.
	d. Air leakage in gas system	● Check access doors, plenum, manifolds, ductwork; repair leaks.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	e. Leakage in dust collection system	● Check for hopper or discharge system leakage; repair as necessary.
	f. Blocked gas system	● Check bags for blinding, obstruction in duct passages, or closed damper; clean or repair as necessary.
	g. Fan and motor sheaves reversed	● Check drawings and reverse sheaves.
	h. System static pressure too high	● Measure static pressure on both sides of fan and discuss with designer of duct velocity and configuration.
	i. Excessive moisture	● Refer to Item 2.d.
	j. Infrequent cleaning	● Refer to Item 6.
6. Improper cleaning system operation		
a. Blowring reversing switch failure (RJ)	a. Worn cams or rollers	● Repair or replace switch assembly.
	b. Improperly set tripper level	● Adjust arc of movement for aproximately 60° above or below horizontal; uneven arc will cause switch to work in only one direction.
	c. Dirt in switch	● Check to see that enclosure is properly installed.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
b. Inability to maintain compressed air pressure (PJ)	a. Faulty or undersized compressor	• Check compressor manual. Pressure should normally be maintained between 80 to 110 psig.
	b. Leakage or restriction in main line.	• Locate and repair leak or restriction.
	c. Defective timer operation	• Make sure all valves are being activated. Check for sticking timer relay or pulse longer than 0.15 second. Replace timer if necessary.
	d. Improper operation of solenoid or diaphragm valves	• Examine valves for dirt or short circuit in wiring which can cause valves to stick open. Clean and check pilot plunger.
	NOTE: Steady rush of air indicates open valve; no air pulse indicates plugged valve. Solenoid valves require a minimum of 5 psig to close. A long compressed air run after the shutoff valve has clogged can prevent the required 5 psig from developing. The solution would be provision of reservoir and shutoff valve near the collector.	
	e. Compressed air consumption too high	• Reduce cleaning cycle, duration of pulse, or supply pressure, if possible.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	f. Plugged dryer	● Replace dessicant or bypass dryer if permitted.
	g. Supply line too small	● Consult design.
	h. Compressor worn	● Replace rings.
c. Reduced compressed air consumption (PJ)	a. Pulsing (solenoid) valves not working	● Check diaphragms, springs, and pilot valves.
	b. Failed timer	● Check terminal outputs.
d. Inadequate cleaning (S)	a. Defective shaker mechanism	● Check shaker speed, amplitude, and bag tension; adjust if required. Check for broken linkage and lost pins connecting linkage.
7. Moisture in baghouse	a. Insufficient preheating	● Run system with hot air prior to starting process gas flow.
	b. System not purged after shutdown	● Keep fan running for 5 to 10 minutes after process is shut down.
	c. Wall temperature below dewpoint	● Raise gas temperature, insulate unit, install auxiliary heaters. Lower dewpoint by keeping moisture out of system.
	d. Cold spots through insulation	● Eliminate direct metal lines through insuation.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	e. Compressed air introducing water (RJ)	● Check automatic drains, install aftercooler, install dryer.
	f. Repressuring air causing condensation (RA)	● Preheat repressuring air; use process gas as source of repressuring air.
	g. Moisture in compressed air line	● Make sure cooler or water trap is functioning.
8. Insufficient dust pickup at emission points	a. Leaks in ductwork, access doors, and/or hopper discharge valves.	● Repair leaks so that air does not bypass source.
	b. High differential pressure	● Refer to Item 2.
	c. Slipping fan belts or fan rotating in wrong direction.	● Check fan and repair as necessary.
	d. Clogged duct or closed or partially closed gate or damper	● Check all ductwork and damper positions and operation.
	e. Duct size or run other than original design/inadequate system design	● Check design specifications with manufacturer. Close open areas around dust source. Check for cross drafts that overcome suction.
9. Fan problems -- excessive wear, noise, vibration, or motor overloading	a. Improper fan	● Check with fan manufacturer to see if fan is of proper design for application.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	b. Fan speed too high	● Consult fan manufacturer.
	c. Dust buildup on fan blades.	● Clean fan and check for water.
	d. Improper fan wheel	● Check with manufacturer.
	e. Sheaves not balanced	● Have sheaves dynamically balanced.
	f. Worn bearings	● Replace bearings.
	g. Air volume too high	● Refer to Item 2.a.
	h. Motor not sized for cold start	● Dampen fan at startup, reduce fan speed, provide heat faster, or replace motor.
10. Hopper/dust discharge system failure or excessive wear		
a. High screw conveyor or wear	a. Screw conveyor or airlock undersized	● Measure hourly collection of dust and consult manufacturer.
	b. Conveyor or airlock speed too high	● Check and reduce speed.
	c. Thermal expansion	● Consult manufacturer.
b. Frequent screw conveyor or airlock failure	a. Undersized equipment	● Consult manufacturer.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
	b. Misaligned screw conveyor	● Check and align.
	c. Overloading components	● Check sizing and design of all components versus dust delivery rates.
c. High pneumatic conveyor wear	a. Blower set too fast	● Check and reduce speed.
	b. Undersized piping	● Review design -- slow down blower or increase pipe size.
d. Pneumatic conveyor pipes plugging	a. Elbows designed with too short a radius	● Replace with long radius elbows.
	b. Overloading pneumatic conveyor	● Review design.
	c. Slug loading of dust	● Feed dust gradually.
	d. Moisture in dust	● Refer to Item 7.
e. Material bridging in hopper	a. Moisture in baghouse	● Refer to Item 7.
	b. Dust being stored in hopper	● Ensure that dust is removed continuously.
	c. Insuficient hopper slope	● Rework or replace hoppers.
	d. Conveyor opening too small	● Use a wide flared trough.

Troubleshooting Guidelines for Common Baghouse Operating Problems (contd.)

Problem or Symptom	Probable Cause	Remedy
f. Excessive corrosion of baghouse structure, bag mountings, wire cages	a. Air inleakage through defective gaskets	• Proper inspection and maintenance.
	b. Missing or damaged insulation	• Replace and repair insulation.
	c. Frequent dewpoint excursions	• Heat tracing and/or gas temperature elevation.

PJ = pulse jet
RA = reverse air
RJ = reverse jet
S = shaker

APPENDIX F

Appendix F contains a typical maintenance schedule which may prove useful to baghouse operators.

Typical Maintenance Schedule for a Fabric Filter System [5, 19, 20, 21, 22, 23]

Inspection Frequency	Component	Procedure
Daily	Stack and opacity meter	Check exhaust for visible dust
	Manometer	Check and record fabric pressure loss and fan static pressure. Watch for trends.
	Compressed air system	Check for air leakage (low pressure). Check valves.
	Collector	Observe all dials, meters, charts, and gauges etc. on control panel and listen to system for properly operating subsystems.
	Damper valves	Check all isolation, bypass, and cleaning damper valves for synchronization and proper operation based upon manufacturer guidelines.
	Rotating equipment and drives	Check for signs of jamming, leakage, broken parts, wear, etc.
Weekly	Filter bags	Check for tears, holes, abrasion, proper fastening, bag tension, dust accumulation on surface or in creases and folds.
	Cleaning system	Check cleaning sequence and cycle times for proper valve and timer operation. Check compressed air lines including oilers and filters. Inspect shaker mechanisms for proper operation.
	Hoppers	Check for bridging or plugging. Inspect screw conveyor flighting for proper operation and lubrication.

Typical Maintenance Schedule for a Fabric Filter System (contd.)

Inspection Frequency	Component	Procedure
Monthly	Shaker mechanism	Inspect for loose bolts.
	Fan(s)	Check for corrosion and material buildup and check V-belt drives and chains for tension and wear.
	Monitor(s)	Check accuracy of all indicating equipment.
Quarterly	Inlet plenum	Check baffle plate for wear; if appreciable wear is evident, replace. Check for dust deposits.
	Access doors	Check all gaskets.
	Shaker mechanism	Tube type (tube hooks suspended from a tubular assembly): inspect nylon bushings in shaker bars and clevis (hanger) assembly for wear. Channel shakers (tube hooks suspended from a channel bar assembly): inspect drill bushings in tie bars, shaker bars, and connecting rods for wear.
Semi-annually	Motors, fans, etc.	Lubricate all electric motors, speed reducers, exhaust and reverse air fans, and similar equipment.
Annually	Collector	Check all bolts and welds. Inspect entire collector thoroughly, clean and touch up paint where necessary.

GLOSSARY

Abrasion, flex - Cloth wear in a creased area caused by excessive bending.

Abrasion, surface - Eroding away of fabric fibers or fiber surface on the duty side of the cloth due to cloth-to-cloth or gas-to-cloth contact.

Acetate - A cellulose-based fiber obtained from plants, wood.

ACFM - Actual cubic feet per minute.

Acid Dewpoint - The temperature at which liquid droplets which are acidic condense from the vapor phase.

Acid Gases - Any gases or liquid droplets which can react with water to form acids: HCl, HF, SO_2, SO_3, NO_X.

Acrylic - A synthetic polymerized fiber that contains at least 85% acrylonitrile.

Aerosol - A stable cloud of solid particles and/or liquid droplets uniformly suspended in a gas (smoke, fog, mist).

Agglomeration - Formation of particle clusters by particle collision due to diffusion and turbulence. Same as coagulation or flocculation.

Air, Standard - Dry air at 65 °F and 29.92" Hg pressure (Density 13.595 gm/cm^3). Equivalent to 0.075 lb/cu ft.

Anemometer - An instrument for measuring the velocity of air or gas.

Annualized Costs - A development of costs wherein both the operating and capital cost are combined and viewed on yearly cost basis.

Aspect Ratio - A way of characterizing the cross-sectional shape of the fiber.

Atmospheric Pressure - The pressure of the atmosphere as measured by means of the barometer at the location specified.

Attrition - Wearing or grinding down by friction. One of the three basic processes contributing to particle formation, the others being condensation and combustion.

GLOSSARY

Backwash - A method of fabric cleaning where direction of filter flow is reversed, accompanied by flexing of the fabric and breaking of the dust cake. Also known as backpressure, repressure, collapse-clean, etc.

Baffle - A plate, grating, or refractory wall used especially to block, hinder, or divert a flow or to hinder the passage of a fluid.

Baghouse - A device containing a fabric filter medium in the shape of a bag, sleeve, envelope, cartridge or pocket, for the purpose of removing particulate entrained in a gas stream.

Barometer - A detector for measuring atmospheric pressure.

Batch cleaning - Usually refers to that process used in heat-cleaning glass cloth in roll form by exposing it to 500-600 °F temperatures for prolonged periods to burn off the starches.

Blast gate - A sliding plate or damper installed in a supply or exhaust duct for the purpose of regulating air flow.

Bleed - Particles of dust or fumes that leak through the bag.

Blinding - A closing of the filter medium pores which results in either a reduced gas flow or an increased pressure drop across the medium. If the medium cannot be cleaned readily nor the pores reopened, this condition is often referred to as "permanent blinding."

Bridge - Material blockage across an opening such as a hopper outlet.

British Thermal Unit (Btu) - The amount of heat required to raise one pound of water by one degree fahrenheit.

Bulked Yarn - Filament yarn that has been processed by high-pressure air passing through the yarn and relaxing it into gentle loops, bends, etc.

Cake - The dust layer developed on the surface of the filter medium during the filtration process.

Calendering - Process in which fabric passes between cold or heated rolls under high pressure. This pushes the surface fibers down into the body of the filter medium.

Capital Charges - Sum of interest, taxes and insurance charges.

Capital Costs - The first cost of equipment investment costs, including equipment installation cost.

Carding (Garnetting) - Mechanical process for forming a non-woven fabric.

Cascade Impactor - Device for determining particle size distribution.

Ceramic Filter - Component of a gas sampling train. These are suitable for high temperature (1000 °F) filtration.

Cloth - In general, a pliant fabric that is woven, knitted, felted of otherwise formed from any textile fiber, wire, or other suitable material.

Cloth Weight - Usually expressed in oz/sq yd. or oz/sq ft. However, cotton sateen is often specified at a certain number of linear yd/lb of a designated width.

Coating - Immersing the filter medium in a solution to provide the fibers with a coating that will lubricate and thereby reduce self-abrasion; in the case of woven-glass bags, the most common coatings have been Teflon and siliconegraphite.

Coefficient of Haze - A measure of light transmission through a soiled filter. Coefficient of haze units are defined as 100 times the optical density as determined by transmittance.

Cold Spot - On an insulated baghouse, a point where a continuous metallic heat transfer circuit through the insulation creates an uninsulated area.

Collection Efficiency - Percentage of dust collected by a control device.

Concentration - Amount of dust in the gas. Usually expressed in terms of grains/cu ft, lb/1000 lb. of gas, ppm, mg/cu m. or lb/million Btu.

Condensation - The process of changing a vapor into liquid by decreasing temperature, increasing pressure, or both. Gas cooling is the most common technique.

GLOSSARY

Coronizing - Thermal process for removing organic sizings from yarns.

Corrosion - Deterioration or physical degradation due to chemical action.

Counter - Instrument for measuring the number and frequently the size of dust particles in an aerosol.

Counting - Determination of the number of dust particles per unit area of a viewing field as with a membrane filter or the number of particles per unit volume of liquid or gas from which airborne particle concentrations can be estimated.

Count Median Size - That particle size for which there are an equal number of particles greater than and less than the median or middlemost size.

Creel - Part of a weaving machine which holds the yarn packages (about 700) and measures 50-75 ft. in length by 12 ft. in width.

Crimp - Waves contained in a yarn.

Cuffing - Sewing operations on the end of a bag.

Cut Size - That size particle which can be collected at a specified efficiency, usually 50 percent.

Cyclone - Device for separating gas from a particulate based on centripetal force and angular momentum.

Damper - An adjustable gate installed in a duct for the purpose of regulating air flow.

Dehumidify - To reduce by any process the quantity of water vapor present in a gas mixture (air).

Denier - The weight, in grams, of 9000 meters of fiber.

Density - The ratio of the mass of a specimen of a substance to the volume of the specimen. The mass of a unit volume of a substance.

GLOSSARY

Diameter, Aerodynamic - The diameter of a sphere of unit density having the same terminal settling velocity as a particle in question, regardless of its geometric size, shape, and true density.

Diaphragm Valve - A compressed air operated valve that is used to pulse clean bags.

Dimensional Stability - Ability of a fabric to retain finished length and width, under stress, in hot or moist atmospheres.

Drag, dP/(G/C) - Normalized value for pressure drop. Pressure drop is divided by the gas-to-cloth ratio. This property allows comparision of one dust/filter medium to another on a common basis and at various parts of the filtration cycle.

Dust - Solid particles less than 100 microns created by the attrition of larger particles. Particles thus formed are not usually called dust unless they are larger than about 1 micron diameter.

Dust Loading - The quantity of dust entrained in the gas stream, usually expressed as grains per cubic foot of gas. (7000 grains = 1 lb).

Electrostatic Filter - Filter using electrostatic charge effects to enhance particle capture.

Emissions - Particulate and chemicals leaving a process (process emissions) or leaving a baghouse (baghouse emissions).

End - Same as warp thread.

End Count - Same as warp count.

Entry loss - Loss in pressure due to air velocity changes caused by duct, hood, and enclosure geometry factors.

Epitropic Fiber - Fiber whose surface contains embedded particles to modify one or more properties of the fiber.

Extensibility - Stretching characteristics of fabric under specified conditions.

GLOSSARY

Fabric - A collective term applied to cloth no matter how constructed and regardless of the kind of fiber used. In the commonest sense, it refers to a woven cloth.

Felled Seam - Vertical seam in a fiber bag which requires an overlap of the material in a particular way.

Felt - Fabric structures constructed by the interlocking action of the fibers themselves, without spinning, weaving, or knitting.

Felted Bag - Type of bag frequently used on pulse-jet collectors. Features a thick mat of fibers supported by a woven backing or scrim.

Fiber - Fundamental unit of a textile raw material.

Filament - A fine or thinly-spun thread.

Fill - Crosswise threads woven by loom. Yarns running from selvage to selvage at right angles to the warps in woven fabrics.

Fill Count - Number of fill threads per inch of cloth.

Filter Cake - The accumulation of dust on a bag. Often assists in the filtration process. Also see Cake.

Filter Media - The permeable barrier employed in the filtration process to separate the particles from the fluid stream.

Filter Velocity - The velocity, feet per minute, at which the air (gas) passes through the filter media, or rather the velocity of approach to the media. The filter capacity rate.

Filtration - A process by which particles are separated from a fluid stream by use of a permeable barrier.

Fines - Particulate matter less than 1 micrometer in diameter.

Finishing - Those processes applied to improve appearance or serviceability of a fabric after weaving.

GLOSSARY

Flame Retardant - A finish designed to repel the combustibility of a fabric, either of a durable or non-durable type.

Flange-to-Flange - The baghouse equipment from inlet flange to outlet flange.

Float - The position of a yarn that passes over two or more yarns passing in the opposite direction.

Flex Test - See MIT flex test.

Fly-Ash - Finely divided particles of ash entrained in flue gases resulting from the combustion of fuel. The ash particles consist of incompletely burned fuel and a variety of mineral constituents.

Fog - Suspended liquid droplets ranging from 5 to 40 microns in diameter, generated by condensation from the gaseous to the liquid state, or by breaking up a liquid into a dispersed state, such as by splashing, foaming and atomizing (see Mist).

French Seam - See felled seam.

Fume - Fine particles dispersed in air or gases, formed by condensation, sublimation or chemical reaction. Particles are usually less than one micron in size.

Gas - Gas is a formless state of matter completely occupying any space. Air is a gas.

Gas-to-Cloth Ratio - The volume of process gas entering the fabric filter dust collector, divided by the amount of cloth area filtering the dust from the gas. Normally the gas flow is given in acfm and the cloth area in square feet. The ratio then has the units ft/min.

Geometric Standard Deviation - The measure of dispersion for a log-normal distribution, the ratio of the 84.13 to the 50 percentile (or the 50 to the 15.87 percentile).

Grain - A unit of weight equivalent to 1/7000 of a pound, or 65 milligrams.

Gravity, Specific - The ratio of a mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water is usually taken as a standard substance. For gases, dry air at the same temperature and pressure as the gas is often taken as the standard substance.

GLOSSARY

Glazing - High pressure pressing of the filter medium at elevated temperatures; fuses surface fibers to the body of the filter medium.

Greige, Greige Goods - Same as grey or unfinished goods.

Gross Gas-to-Cloth Ratio - The total inlet gas volumetric flow rate (including any cleaning air) divided by the total available filter media (cloth).

Harness - The frame used to raise or lower those warp yarns necessary to produce a specific weave, at the same time permitting the filling to be passed through by the shuttle.

Haze - A state of atmospheric obscuration due to the presence of fine, solid and/or liquid particles in stable suspension; visibility exceeds 1 but is less than 2 km. The particles are so small that they cannot be sensed via impact or thermal effects nor seen with the naked eye.

Header - A pressurized pipe that contains the compressed air supply for a pulse type baghouse.

Heat, Specific - The heat absorbed (or given up) by a unit mass of a substance when its temperature is increased (or decreased) by one degree. The common unit is the Btu per degree Fahrenheit. For gases, both specific heat at constant pressure (c_p) and specific heat at constant volume (c_v) are frequently used.

Hood Suction - The entry loss plus the velocity pressure in the connecting duct.

Hopper - Storage container at the bottom of a collection device to hold the dust.

Humidity, Absolute - The weight of water vapor carried by a unit weight of dry air or gas. Pounds of water vapor per pound of dry air; grains of water vapor per pound of dry air.

Humidity, Relative - The ratio of the absolute humidity in a gas to that of the saturated gas at the same temperature.

Hydrolysis - Degradation of polymer chains due to reaction with water.

Hydrophilic Fibers - Fibers that readily absorb water.

Hydrophobic Fibers - Fibers that do not readily absorb water.

Impaction - A particle collision with a collection surface caused by the interaction of inertial and hydrodynamic forces.

Inch of Water - A unit of pressure equal to the pressure exerted by a column of liquid water one inch high at a standard temperature. The standard temperature is normally taken as 70 °F. One inch of water at 70 °F = 5.196 lb per sq. ft.

Indirect Yarn Number - The inverse of yarn number, i.e., length of yarn per unit mass of yarn.

Interfacing - Points of contact between the warp and filling yarns in a fabric.

Interstices - Openings between the interlacings of the warp and filling yarns in a fabric.

Isokinetic Sampling - Extraction of an aerosol by a sampling probe such that the fluid velocity entering the probe is the same as that at the sampling location in the parent gas stream. Deviation from isokinetic conditions can lead to incorrect estimates of mass particulate concentrations.

K Factor - The specific resistance of the dust cake, inches of water gauge per pound of dust per square foot of filter area per feet per minute filtering velocity.

Lime - Calcium oxide, CaO. Also known as burnt lime, calx, quicklime, caustic lime.

Limestone - Calcium carbonate, $CaCO_3$.

Loading - See Dust Loading.

Loom Finish - Same as Greig Cloth.

Maintenance Cost - Sum of bag replacement cost and routine maintenance cost.

Manometer - An instrument for measuring pressure; a U-tube partially filled with a liquid, usually water, mercury or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Membrane - A thin layer of permeable material.

Micrometer (micron) - A unit of length, the thousandth part of 1 mm or the millionth of a meter (approximately 1/25,000 of an inch).

Mist and Fog - A distinction sometimes made between mist and fog is of minor importance since both terms are used to indicate the particulate state of airborne liquids. Mist is a visible emission usually formed by a condensation process or a vapor-phase reaction, the liquid particles being sufficiently large to fall of their own weight.

MIT Flex Endurance Test - A test whereby a filter media specimen is rapidly flexed in an arc under a specified load until fabric rupture occurs. Test conditions are usually: 270° arc, 180 cycles/minute, 4 pound load, 1/2 inch width specimen.

Modacrylic - A synthetic polymerized fiber that contains less than 85% acrylonitrile.

Mole - The weight of a substance numerically equal to its molecular weight. If the weight is in pounds, the unit is "pound moles." For dry air at 70 °F and a pressure of one atmosphere, there are 29 pounds per pound mole and 386 cubic feet per pound mole (thus a density of 0.075 lb/ft^3).

Mullen Burst - Pressure necessary to rupture a secured specimen of cloth; usually expressed in psi.

Multifilament (Multifil) - Yarn composed of several filaments, which are continuous strands of fiber of indefinite length.

Napping - A scraping of the filter-medium surface that raises the surface fibers. The rupturing of the filling yarns to produce a fleecy surface on woven fabrics.

Needled Felt - A felt constructed by the use of barbed needles moving up and down, pushing and pulling the fibers to form an interlocking of adjacent fibers.

Net Gas-to-Cloth Ratio - The total inlet gas volume divided by only the on-stream filter media. For example, if one cell is off stream for cleaning, this will be deducted from the total available cloth area before calculating the net gas-to-cloth ratio.

Net Gas-to-Cloth Ratio = Total Inlet Gas Volumetric Flow/On Stream Cloth Area.

Nonwoven Felt - A felt made either by needling, by matting of fibers, or by compressing with a bonding agent for permanency.

NO_x - Oxides of Nitrogen.

Nomex ® - An aromatic polyamide fiber.

Nylon - The generic name for a polyamide polymer.

Olefin - A manufactured fabric in which the fabric forming substance is any long-chain synthetic polymer composed of at least 85% by weight of ethylene, propylene, or other olefin units.

Opacity - The transmissivity of a stack plume. A perfectly clear plume (100% light transmission) has zero opacity. A plume that transmits no light at all has 100% opacity.

Operating Costs - The costs associated with operating equipment, including power, maintenance and any consumable item costs.

Particle - A small discrete mass of solid or liquid matter such as dust, fume, mist, smoke, and fog.

Particulate matter- Any dispersed matter, solid or liquid, in which the individual particles or agglomerates may range from 0.002 micron up to 500 microns. Particle lifetimes in the suspended state range from a few seconds to several months. Additional terms used to describe particulate matter may include dust, fly ash, smoke, soot, droplets, mist, fog, and fumes.

Penetration - That fraction or percent of a particulate material that passes through a dust collector and discharges to the atmosphere.

Permeability - A measure of fabric porosity or openness, usually expressed in cfm or air/sq ft of fabric with a 0.5 in H_2O pressure differential.

GLOSSARY

Pick - Same as filling.

Pitot Tube - A means of measuring velocity pressure. A device consisting of two tubes - one serving to measure the total or impact pressure existing in an air stream, the other to measure the static pressure only. When both tubes are connected across a differential pressure measuring device, the static pressure is compensated automatically and the velocity pressure only is registered.

Plain Weave - A weave in which each warp yarn passes alternately over each filling yarn.

Plenum Chamber - An air compartment maintained under pressure, and connected to one or more ducts. A pressure equalizing chamber.

Ply - Two or more yarns joined together by twisting.

PM_{10} - Particulate matter of diameter under 10 microns.

Porosity - Sometimes erroneously used as a synonym for permeability. Originally a designation for the amount of air in a fabric, i.e. blankets.

Pre-coat - Material added to air stream in initial process startup to aid in establishing filter cake on bags.

Preshrunk - Usually a hot aqueous immersion of the cloth to eliminate its tendency to shrink in further wet performance.

Pressed Felt - A type of felt manufactured by pressing fibers into a scrim.

Pressure, Atmospheric - The pressure due to the weight of the atmosphere, as indicated by a barometer. Standard atmospheric pressure is 29.92 " of mercury. Equivalents in other units are 760 mm of mercury, 14.7 psia, and 407 inches of water column.

Pressure Drop - Resistance to gas flow; may refer to pressure differential across the cloth, across the baghouse, or across the entire system. Units are usually inches of water.

GLOSSARY

Pressure Drop Ratio - Ratio of pressure drop with an electric field to pressure drop without such a field, all other conditions being the same.

Pressure, Gauge - Pressure measured from atmospheric pressure as a base. Gauge pressure may be indicated by a manometer which has one leg connected to the pressure source and the other exposed to atmospheric pressure.

Pressure Loss - The pressure required to overcome the resistance to gas flow in a system that includes the resistance of straight runs of pipe, entrances to headers, bends, elbows, orifice losses, and pressure drop through gas cleaning devices.

Pressure, Static - The pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches of water gauge, when dealing with air.

Pressure, Total - The algebraic sum of the velocity pressure and the static pressure (with due regard to sign). In gas-handling systems these pressures are usually expressed in inches water gauge.

Pressure, Velocity - The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches water gauge.

Pulse Cycle - The interval of time between one pulsing of a row of bags and the next pulsing of the same row.

Pulse Interval - See Pulse Cycle.

Pulse Jet - Generic name given to all pulsing collectors. Gas flow is from outside to inside of bags.

Redundancy - Extra baghouse modules so that any module(s) can be removed from service for maintenance while normal operation is maintained. For a small baghouse, redundancy requires a complete, separate baghouse.

Resistance - Analagous to electrical resistance; the pressure drop across the filtering media and dust cake, expressed in inches water gauge.

Retro-Fit - The addition of a baghouse system to an already-existing process.

GLOSSARY

Reverse-Air Baghouse - A unit employing reverse flow flushing air to clean the dust from the bags. Dirty gas flow is inside-to-outside of bags. Reverse air is outside-to-inside of bags.

Ring Covers - Fabric envelope enclosing the rings to prevent the bags in reverse-air collectors from collapsing during cleaning.

Rings - Metal bands sown in the bag at various intervals to prevent bag from total collapse while cleaning.

RYTON ® - Polymerized Phenylene Sulfide

Satin (Sateen) Weave - Type of weave in which the pattern of fill yarns produces a smooth, lustrous finish.

SCFM - Specific cubic feet per minute.

Scour - A soap-and-water wash to "off-loom" fabric.

Scrim - A very loosely woven fabric onto which felt is needled.

Seam Registration - Alignment of filling yarn when a bag is being sewn (tubed).

Seeding - The application of a relatively coarse, dry dust to a bag before start-up to provide an initial filter cake for immediate high efficiency and to protect bags from blinding.

Selvage - The binding on the lengthwise edge of a woven fabric.

Service Module - A compartment in a pulse-jet baghouse where valves, piping, wiring, and timers are located.

Shaker Baghouse - A unit wherein cleaning is accomplished by shaking the bags.

Shaker Cleaning - Tops of bags are shaken. Gas flows inside to outside of bags.

Shrinkage - Reduction in warp-direction length or fill-direction length.

Silicone Finish - A treatment with silicone to provide a slick finish for improved dust release.

Singeing - Passing of the filter medium over an open flame, thereby removing the protruding surface fibers.

Singles - Term used to imply only one yarn.

Sintering - Compression of a heated metal powder at a temperature below the melting point.

Sizing - A protective coating applied to yarn to ensure safe handling.

Slaked Lime - Calcium hydroxide, $Ca(OH)_2$.

Slaking - Exothermic reaction of water with lime to produce slaked lime, $Ca(OH)_2$.

Slashing - Process in which a protective coating is applied to each warp yarn.

Slippage - The movement of yarns in a fabric due to insufficient interlacings.

Smoke - Small gas-borne particles usually resulting from incomplete combustion. Such particles consist predominantly of carbon and other combustible material and are present in sufficient quantity to be observable independently of other solids.

Sonic Cleaning - Sonic energy from air-powered horns produces shock waves which enhance dust removal from fabrics.

Soot - An agglomeration of carbon particles impregnated with "tar" formed by the incomplete combustion of carbonaceous material. These particles, which are much larger than those constituting a true smoke, are highly visible to the naked eye.

SO_x - Oxides of Sulfur, SO_2 and/or SO_3.

Spray Dryer - A device into which an aqueous slurry of solution is sprayed and all of the water evaporated adiabatically.

Specific Gravity - A dimensionless quantity defining the ratio of the density of a substance at a given temperature to the density of some reference material (usually water for liquids and air for gases).

GLOSSARY

Specific Heat - The heat absorbed (or given up) by a unit mass of a substance when its temperature is increased (or decreased) by one degree. Common units are Btu/lb-°F or cal/g-°F. For gases, both the specific heat at constant pressure (c_p) and the specific heat at constant volume (c_v) play key thermodynamic roles, particularly so when the flow is compressible.

Specific Volume - The volume of a substance per unit mass; i.e., the reciprocal of density, usually given in cubic feet per pound or cubic meters per gram.

Specific Resistance Coefficient of the Filter Cake - An indicator of how rapidly pressure drop increases during filtration.

Spun Fabric - Fabric woven from staple spun fiber; same as staple.

Spunbonded - A non-woven fabric formed by producing, laying and self-bonding a web of filamentous material in one continuous set of processing steps. Usually made of polyester, polyamides or olefins.

Standard Atmosphere - The pressure exerted by a column of mercury 29.92 inches high at 70 °F; approximately 14.71 psi. See Pressure, Atmospheric.

Staple Fiber - Short fiber cut to specific length in synthetics. 1 in., 2 in., 2 in., etc. Also, natural fibers of a length characteristic of fiber, animal fibers being the longest.

Strand - A group of filaments; when twisted together, these constitute a yarn.

Substrate - See Filter Medium.

Teflon - Polytetrafluroethylene.

Temperature, absolute - Temperature expressed in degrees above absolute zero.

Temperature, Dew-Point - The temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100 percent relative humidity) for a given absolute humidity at constant pressure.

Temperature, Dry-Bulb - The temperature of a gas or mixture of gases indicated by an accurate thermometer after correction for radiation.

GLOSSARY

Temperature Scales - Temperature scales, Centigrade (Celcius) and Fahrenheit derive their degree value by dividing the difference between the ice point and steam points of water as follows: Centigrade 100 and Fahrenheit 180. The value of a Fahrenheit degree is therefore 5/9 of a Centigrade degree. The Fahrenheit scale is generally used in air handling practice. The Rankine scale, sometimes called Fahrenheit absolute, has its zero as the lowest attainable temperature, exactly 459.67 degrees below the zero of the Fahrenheit scale. To convert Fahrenheit to Rankine temperature (generally designated R), add 459.67 degrees (460 is sufficiently accurate).

Temperature, Wet-Bulb - Wet bulb temperature is a measure of the moisture indicated by a wet bulb psychrometer.

Tensile Strength - A measure of the ability of yarn or fabric to resist breaking by direct tension.

Tenter Frame - A machine for drying cloth under tension. (Tentering: Also called framing.)

Tex Number - System in which 1 Tex is equal to 9 denier.

Textile - That which is or may be woven.

Thread - An assemblage of fibers used to sew fabrics together.

Thread-count - The number of warp and filling yarns in a fabric.

Throw - A process of doubling or twisting fibers into a yarn of the desired size and twist.

Transmissometer - An instrument for measuring the extinction coefficient of the atmosphere for the determination of visibility range. Also called telephotometer, transmittance meter, hazemeter, or smoke density indicator.

Tube Sheet - The steel plate that bags are suspended from in a baghouse.

Tubing - Sewing of fabric in the form of a tube when making a filter bag.

GLOSSARY

Turnkey - Complete baghouse system including all dust pickups, ducting, dust discharge auxiliaries and all equipment which is part of the dust collection system.

Twill Weave - Warp yarns floating over or under at least two consecutive picks from lower left to upper right, with the points of intersection moving one yarn outward and upward or downward on succeeding picks, causing diagonal lines in the cloth.

Twist - The number of complete spiral turns in a yarn in a right or left direction, i,e,. "Z" or "S", respectively.

Vapor - The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature.

Velocity, Capture - The air velocity at any point in front of the hood or at the hood opening necessary to prevent particulate material and contaminant gases from escaping to the working area.

Velocity Head - Same as velocity pressure.

Velocity of Approach - The velocity of air (gas), feet per minute, normal to the face of the filter media.

Velocity, Transport (Conveying) - The minimum air velocity required to transport particulate matter in any air stream, especially confined duct or pipe flows (vertical or horizontal) so that no sedimentation takes place.

Velocity Traverse - A method of determining the average air velocity in a duct. A duct, round or rectangular, is divided into numerous sections of equal area. The velocity is determined in each area and the mean is taken of the sum.

Vinyon - A fiber composed of a polymer containing at least 85% by weight vinyl chloride units.

Viscosity - The proportionality constant relating shear rate to shear stress that is expressed in units of poise, centipoise, or pounds per foot-second.

Volume, Specific - The volume of a substance per unit mass; the reciprocal of density; usually given in cubic feet per pound, etc.

GLOSSARY

Warp - The yarn running lengthwise (machine direction) in a woven fabric.

Warp Count - Number of warp threads per inch of width.

W.C. - Water column

Weave - The pattern of weaving, i.e. plain twill, satin, etc.

Weft - Same as filling.

Woof - Same as filling.

Worsted Yarn - Yarn whose fibers are combed before being spun.

Wovens - Filter media fabrics constructed solely by weaving or interlacing yarns more or less at right angles into a uniform structure.

Yarn - A term for an assemblage of fibers of filaments forming a strand which can be woven or otherwise formed into a textile material.

Yarn Number - Mass of yarn per unit length of yarn.

Yarn Size - A relative measure of fineness or coarseness of yarn. In spun yarns, the smaller the number, the coarser the yarn.

GLOSSARY

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